NEARSHORE HABITAT USE BY JUVENILE CHINOOK SALMON IN LENTIC SYSTEMS OF THE LAKE WASHINGTON BASIN, ANNUAL REPORT, 2002

by

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ABSTRACT

In 2002, we continued our assessment of the habitat use of juvenile Chinook salmon (*Oncoryhnchus tshawytscha*) in the nearshore areas of Lake Washington and Lake Sammamish. Juvenile Chinook salmon are found in Lake Washington and Lake Sammamish between January and July, primarily in the littoral zone. Little is known of their habitat use in lakes, as ocean-type Chinook salmon rarely occur in lakes throughout their natural distribution. Research efforts in 2002 focused on juvenile Chinook salmon distribution, shoreline structure use (small woody debris and overhanging vegetation), use of nonnatal tributaries, and abundance at restoration sites. Data on Chinook salmon habitat use were collected primarily through snorkel surveys.

We repeatedly surveyed 12 index sites in south Lake Washington to examine the temporal and spatial distribution of juvenile Chinook salmon. We surveyed four sites on the east shoreline, five on the west shoreline, and three on Mercer Island. From January to the beginning of June, the two sites closest to the Cedar River had substantially higher densities of Chinook salmon than the other sites. Overall, the abundance of Chinook salmon displayed a strong, negative relationship with the shoreline distance from the mouth of the Cedar River to each site. During the latter part of June, we observed fewer Chinook salmon but those that were observed were located primarily along the west shoreline. Juvenile Chinook salmon were present on Mercer Island on each survey date (March 24 – June 16). We found little difference between densities on Mercer Island and those on east and west shoreline sites that were a similar distance away from the Cedar River.

We continued to monitor City of Seattle restoration sites, both pre- and post-project, to help determine if lake shoreline habitat can be improved for juvenile Chinook salmon rearing. A restoration project at Seward Park was completed in December 2001. The restored sites as well as other shoreline sites were surveyed in 2002 and compared to 2001 data. Few juvenile Chinook salmon were observed in Seward Park in 2002. Almost half of the Chinook salmon were at the southern-most site. Only seven Chinook salmon were observed at the restoration site. We found no evidence of increased Chinook salmon use of the restoration site from 2001 to 2002. Overall, the abundance of juvenile Chinook salmon in Seward Park was higher in 2001 than 2002.

We continued to collect baseline information at Beer Sheva Park. In addition, we began monitoring Martha Washington Park to collect baseline data. The boat ramp area at Beer Sheva Park had higher densities of Chinook salmon than other sites. On one survey (May 16), we observed 82 Chinook salmon at the boat ramps. Therefore, there appeared to be sufficient numbers of juvenile Chinook salmon at Beer Sheva Park to colonize Mapes Creek if it were restored. At Martha Washington Park, which is mostly armored with rip rap, we only observed two Chinook salmon in three surveys of a 100-m shoreline section.

Woody debris experiments were conducted again in Gene Coulon Park; however, in 2002, we began the experiments earlier (beginning of March) and we used seven shoreline sections (three woody debris and four open or control sites) instead of four (two woody debris and two controls). Overall, we found little difference between woody debris sites and open sites; however, on a couple of dates in April, almost all of the Chinook salmon were located in the woody debris sites. For the most part, Chinook salmon during the day were observed on the

outside edge of the woody debris piles and were active, but occasionally we observed groups of Chinook salmon that were inactive and located directly under the woody debris

In addition to woody debris experiments, we monitored two natural sites in south Lake Washington with overhanging vegetation and small woody debris (OHV/SWD). We compared areas with OHV/SWD to adjacent sites without OHV/SWD. Both sites were surveyed during the daytime once a week from March to June. Juvenile Chinook salmon were present at these sites from March to the middle of May. At both sites, juvenile Chinook salmon were more abundant at the OHV/SWD locations. Over 80% of juvenile Chinook salmon were located at the OHV/SWD sites. Chinook salmon were usually inactive and located within the OHV/SWD.

We surveyed nine tributaries in south Lake Washington, four in north Lake Washington, and four in south Lake Sammamish. At each tributary, we surveyed four general habitat types, which included: a lake reference site, delta area, convergence pool, and lotic habitats (pools, glides, and riffles within the tributary). The reference site and delta were within the lake and the pools and glides and convergence pool were in the tributary itself. The reference site was a nearby lake shoreline site that appeared to have good quality habitat for juvenile Chinook salmon. In comparison to lake reference sites, the delta sites had a higher density of juvenile Chinook salmon in 9 of 14 sites. On average, the delta sites had almost twice as many fish as the lake reference site. Deltas probably have good Chinook salmon habitat because they are shallow, have a gentle slope, and are composed primarily of sand. Of the other tributary habitats, Chinook salmon were most common in the convergence pools. Overall, Chinook salmon appeared to use tributaries that had low gradient, were relatively small and shallow, and were close to their natal stream (Cedar River or Issaquah Creek). Of the tributaries examined, Johns Creek was by far the most used by Chinook salmon. The peak number of Chinook salmon observed in an index area (lower 0.26 km) of Johns Creek was 387. Chinook salmon were observed as far upstream as 0.46 km from Lake Washington.

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INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) primarily occur in large rivers and coastal streams (Meehan and Bjornn 1991) and are not known to commonly inhabit lake environments. Consequently, little research has been conducted on their habitat use in lakes. Within the Lake Washington basin, juvenile Chinook salmon inhabit lentic environments, either as a migratory corridor from their natal stream to the marine environment (mostly in June) or as an extended rearing location before outmigrating (January-July) to the marine environment. Prior to 1998, little research had been conducted on juvenile Chinook salmon in the lentic environments of the Lake Washington system. Initial work in 1998-2000 focused on macrohabitat use and indicated that juvenile Chinook salmon in Lake Washington are primarily restricted to the littoral zone until mid-May when they are large enough to move offshore (Fresh 2000). Subsequent research in 2001 focused on mesohabitat and microhabitat use (Tabor and Piaskowski 2002). Results indicated juvenile Chinook salmon were concentrated in very shallow water, approximately 0.4 m depth, and prefer low gradient shorelines with small substrates such as sand and gravel. Armored banks, which make up 71% of the Lake Washington shoreline (Toft 2001), reduce the quality and quantity of the nearshore habitat for juvenile Chinook salmon.

In 2002, we continued to examine the habitat use of juvenile Chinook salmon in the nearshore areas of Lake Washington and Lake Sammamish. This report outlines research efforts which focused on juvenile Chinook salmon distribution, shoreline structure use (small woody debris and overhanging vegetation), use of non-natal tributaries, and abundance at restoration sites.

STUDY SITE

We examined habitat use of juvenile Chinook salmon in Lake Washington and Lake Sammamish. Lake Washington is a large monomictic lake with a total surface area of 9,495 hectares and a mean depth of 33 m. The lake typically thermally stratifies from June through October. Surface water temperatures range from 4-6°C in winter to over 20°C in summer. During winter (December to February) the lake level is kept low at an elevation of 6.1 m. Starting in late February the lake level is slowly raised from 6.1 m in January to 6.6 m by May 1 and 6.7 m by June 1. The Ballard Locks, located at the downstream end of the Ship Canal, control the lake level. Over 78% of the lake shoreline is comprised of residential land use. Shorelines are commonly armored with riprap or bulkheads. Man-made overhead structures (i.e., docks, piers, houses) are common along the shoreline. Natural shoreline structures, such as small and large woody debris and emergent vegetation, are rare.

The major tributary to Lake Washington is the Cedar River, which enters the lake at its southern end. The river originates at approximately 1,220 m elevation and over its 80-km course falls 1,180 m. The lower 55 km downstream of Cedar Falls are accessible to anadromous salmonids. Prior to 2003, only the lower 35 km were accessible to anadromous salmonids. Landsburg Dam, a water diversion structure, prevented Chinook salmon from migrating further upstream. A fish ladder was completed in 2003, which allows access past Landsburg Dam to an additional 20 km of the Cedar River. Besides Chinook salmon, anadromous salmonids in the Cedar River includes sockeye salmon, coho salmon and steelhead Sockeye salmon are by far the most abundant anadromous salmonid in the river. Adult returns in excess of 250,000 fish have occurred in some years. Because of water quality issues, sockeye salmon will not be allowed past Landsburg Dam.

Historically, the Duwamish River watershed, which included the Cedar River, provided both riverine and estuarine habitat for indigenous Chinook salmon. Beginning in 1912, drainage patterns of the Cedar River and Lake Washington were extensively altered (Weitkamp and Ruggerone 2000). Most importantly, the Cedar River was diverted into Lake Washington from the Duwamish River watershed, and the outlet of the lake was rerouted through the Ship Canal. These activities changed fish migration routes and environmental conditions encountered by migrants.

Lake Sammamish is within the Lake Washington basin and is located just east of Lake Washington. Lake Sammamish has a surface area of 1,980 hectares and a mean depth of 17.7 m. Most of the shoreline is comprised of residential land use. Issaquah Creek is the major tributary to the lake and enters the lake at the south end. A Washington Department of Fish and Wildlife salmon hatchery (Issaquah State Hatchery), which propagates Chinook salmon and coho salmon, is located at river kilometer 4.8.

Adult Chinook salmon enter the Lake Washington system from Puget Sound through the Chittenden Locks in July through September. Peak upstream migration past the locks usually occurs in August. Adult Chinook salmon begin entering the spawning streams in September and continue until November. The majority of the adult run of Chinook salmon returns to the Issaquah Creek hatchery. Chinook salmon spawn below the hatchery and other adults are allowed to migrate upstream of the hatchery if the hatchery production goal of returning adults is met. The largest run of wild Chinook salmon in the Lake Washington basin occurs in the Cedar River. Large numbers of adult fish also spawn in Bear Creek. Small numbers of fish spawn in several tributaries to Lake Washington and Lake Sammamish. Spawning occurs from October to December with peak spawning activity usually in November. Fry emerge from their redds from January to March and migrate to Lake Washington or Lake Sammamish from January to July. Juvenile Chinook salmon are released from the Issaquah Hatchery in May or early June and large numbers enter Lake Sammamish a few hours after release (Brian Footen, Muckleshoot Indian Tribe, personal communication). Juveniles primarily migrate past the Chittenden Locks in June and July. Juveniles migrate to the ocean in their first year, and thus Lake Washington Chinook salmon are considered “ocean-type” fish.

METHODS

INDEX SITES

We surveyed 12 sites biweekly in south Lake Washington to determine the temporal and spatial distribution of juvenile Chinook salmon. A total of 12 sites were surveyed, five on the west shoreline, four on the east shoreline and three on Mercer Island (Figure 1). Two additional index sites were also surveyed in Gene Coulon Park to replicate sampling efforts in 2000 and 2001. We selected sites with sand and small gravel substrate and a gradual slope; nearshore habitat that juvenile Chinook salmon typically prefer (Photo 1). Many of the sites are public swimming beaches. West and east shoreline sites were surveyed from early February to mid-July. Mercer Island sites were surveyed from late March to mid-June. At each site, a 50- to 100-m transect was established depending on the amount of high quality habitat available (sandy beach with gradual slope). Two transects were surveyed at each site, 0.4 and 0.7 m depth contour. Surveys were all done at night. Snorkelers swam parallel to shore with an underwater flashlight, identifying and counting fish. Transects widths were standardized to 2.5 m (0.4 m depth) and 2 m (0.7 m depth). Snorkelers visually estimated the transect width and calibrated their estimation at the beginning of each survey night by viewing a pre-measured staff underwater.

Fish densities (Chinook salmon/m^2) were calculated by dividing the number of Chinook salmon observed by the area surveyed for each site and transect. A regression was developed between Chinook salmon density and distance of each site from the mouth of the Cedar River. To compare densities between east and west shorelines, a Mann-Whitney U test was conducted for each sample date. To compare individual sites over the study period, we used a Wilcoxon test.

The habitat conditions of each index site were measured in late March 2002 (Table 1). Variables measured included: transect length; substrate composition; distance from shore to 1 m depth; depth at 1 m from shore, and the presence, type, and depth of shoreline armoring. Substrate, distance from shore to 1 m depth, and depth at 1 m from shore were measured systematically such that 10 equally spaced measurements were taken along each transect. The starting point was randomly chosen. The 10 measurements were averaged to obtain an overall transect estimate. For substrate, we visually estimated the percentage of six pre-defined size categories within 1-m-diameter circles along both depth contours, 0.4 and 0.7 m depth. Substrate categories were: sand (<5 millimeters (mm), gravel (5-49 mm), cobble (50-249 mm), boulder ($\geq$250 mm), and other (e.g., organic, wood, metal).

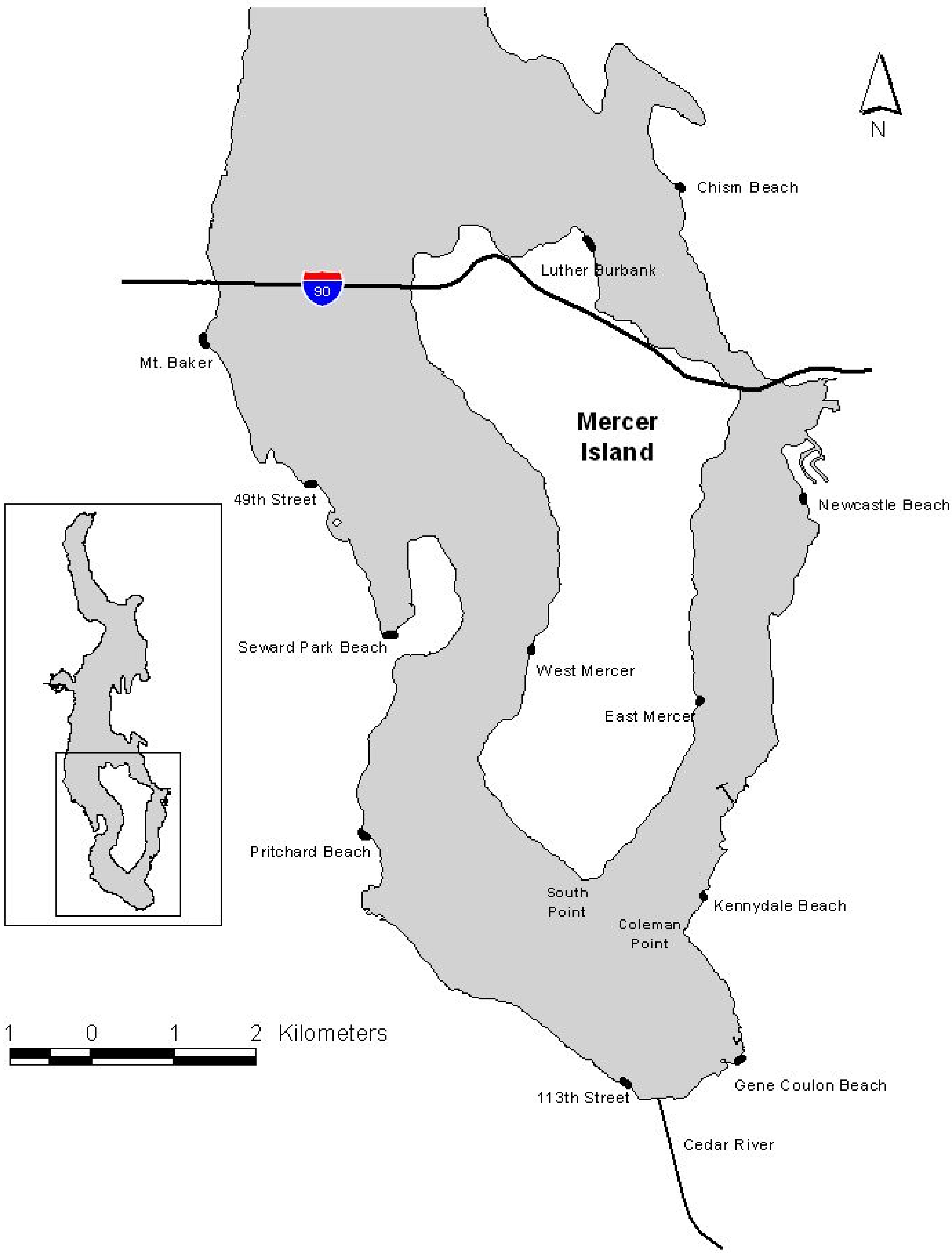


FIGURE 1.—Location of 12 index sites in south Lake Washington used to study the temporal distribution of juvenile Chinook salmon, January-July, 2002. The Cedar River, the major spawning tributary for Chinook salmon in south Lake Washington, is also shown.

PHOTO 1.—Index site at the swim beach of Gene Coulon Park. The shoreline shows the type of habitat (fine substrate with a gentle slope) we tried to find for the other index sites.

TABLE 1. Distance from the mouth of the Cedar River and habitat characteristics of index sites surveyed in southern Lake Washington, January-July, 2002. The distance from Cedar River is an approximate length of the shoreline from the mouth of the Cedar River to each site. To approximate the distance to Mercer Island sites, we used the distance from the mouth of the Cedar River to Coleman Point and from Coleman Point to South Point on Mercer Island and then the distance from South Point to each site (see Figure 1).

Shoreline Site	Distance from Cedar River (km)	Transect length (m)	Substrate	Distance to 1 m depth (m)	Bulkhead length (m)
West					
113th Street	0.5	96	60% sand, 38% gravel, 2% cobble	12.5	63
Pritchard Beach	5.7	78	98% sand, 2% gravel	23.3	0
Seward Park Beach	12.0	53	94% sand, 6% gravel	22.9	16.5
49th Street	14.6	78	51% sand, 41% gravel, 8% cobble	33.5	0
Mt. Baker	17.0	122	38% sand, 41% gravel, 21% cobble	11.3	0
East					
Gene Coulon Beach	1.3	60	100% sand	18	0
Kennydale Beach	4.0	73	64% sand, 36% gravel	15	60
Newcastle Beach	9.4	66	75% sand, 16% gravel, 9% cobble	19.6	0
Chism Beach	15.0	50	88% sand, 10% cobble, 2% gravel	13.3	19.3
Mercer Island					
East Mercer	7.6	73	56% sand, 27% gravel, 17% cobble	14.4	23
West Mercer	8.2	70	51% sand, 31% gravel, 18% cobble	13.7	0
Luther Burbank	14.7	115	61% gravel, 19% sand, 11% boulder, 9% cobble	7.7	0

RESTORATION SITES

In 2002, we continued to monitor City of Seattle restoration sites, both pre- and post-project, to help determine if lake shoreline habitat can be improved for juvenile Chinook salmon rearing. A restoration project at Seward Park was completed in December 2001. The restored sites as well as other shoreline sites were surveyed in 2002 and compared to 2001 data. We continued to collect baseline information at Beer Sheva Park. In addition, we began monitoring Martha Washington Park to collect baseline data.

Seward Park. In December 2001, the City of Seattle and the Army Corps of Engineers (ACOE) deposited 2,000 tons of gravel along a 300-m shoreline section in the northeast part of the park. This shoreline section was divided into two equal sections. The north section (site 3b) received fine substrate and the south section (site 3a) received coarse substrate. The general composition of the substrate was 2.5 to 7.5 cm for the north section and 7.5 to 15 cm for the south section. A more detailed description of the substrate is given in Table 2. The new substrate extended out approximately 5 m from shore.

We surveyed the same sites (Figure 2) from Tabor and Piaskowski (2002); however, we expanded site 3 from 100 m to two 152-m transects to survey the entire restoration site. Survey protocols in 2002 were the same as restoration project monitoring survey methods used by Tabor and Piaskowski (2001). We surveyed along one 0.4 m depth contour. Night surveys were conducted biweekly from mid-March to mid-July.

TABLE 2. Summary table of substrates placed at Seward Park on site 3 for shoreline restoration by the City of Seattle and the U.S. Army Corps of Engineers (ACOE) on December 22-23, 2001 (unpublished data, ACOE). The course substrate was placed at the south section of the restoration site and the fine substrate at the north section. ND = no data.

	Percent passing by weight	
Standard sieve size in inches (mm)	Coarse	Fine
6.0 (152.4)	100	100
3.0 (76.2)	50 - 100	90 - 100
1.5 (38.1)	ND	60 - 90
0.75 (19.1)	0 - 40	ND
0.38 (9.5)	0 - 6	ND
0.19 (4.7)	ND	40 - 70
0.017 (0.4)	ND	15 - 45
0.003 (0.08)	0 - 3	0 - 3

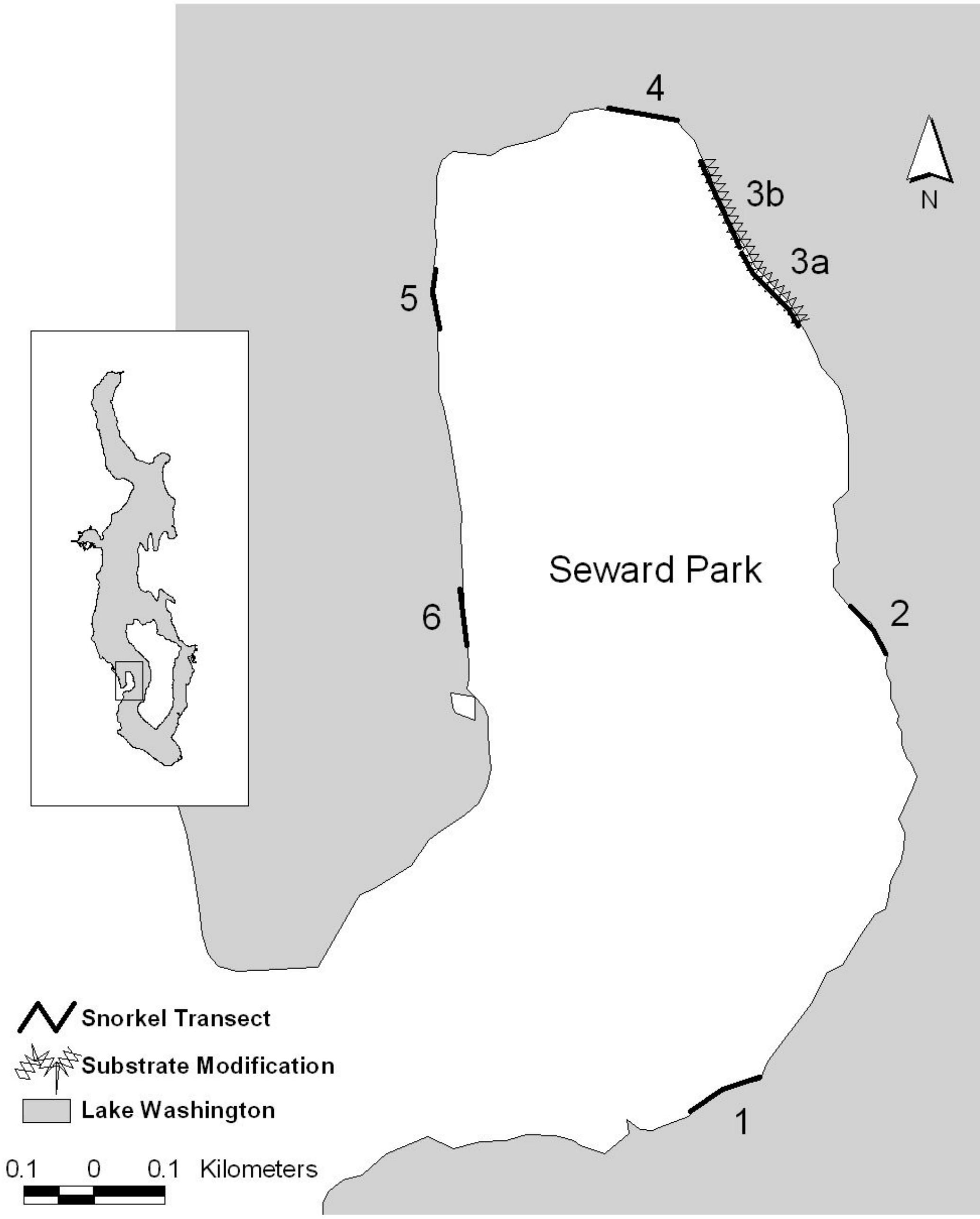


FIGURE 2.—Location of snorkel transects in Seward Park, Lake Washington, March-July, 2002. The location of the December 2001 substrate modification project is also shown.

Beer Sheva Park.—At Beer Sheva Park, the City of Seattle has proposed to day light Mapes Creek (Figure 3), which currently is in a culvert and enters the lake at a few meters below the lake surface. We continued our monitoring of Beer Sheva Park in 2002 to provide an estimate of the temporal abundance of juvenile Chinook salmon in the vicinity of Mapes Creek. Survey sites were expanded in 2002 to include coverage of the boat ramp area. The study area was divided into three sampling sites, the boat ramp site, the northwest site, and the northeast site (Photo 2). Beer Sheva Park occurs along the west shoreline (Figure 3) within a small cove where fine soft sediments (silt/mud) predominate except along the boat ramps. The boat ramp site was 65 m long. It included four boat ramps totaling 42 m and a 23-m shoreline section at the south end of the boat ramps. The average distance to from the shore to one-meter depth was 6.9 m. The northwest site started at the northern boat ramp edge and was 58 m long. Mapes Creek enters the lake in the middle of this transect. The site was along a gravel shoreline with little riparian vegetation except a grass lawn. Close to shore the substrate was gravel but a short distance offshore the substrate was silt and mud. The average distance to one-meter depth was 12.1 m. The northeast site started at the chain-link fence at the edge of the park lawn and extended 128 m east to a long narrow private dock. This site had abundant riparian vegetation as well as aquatic macrophytes. The slope was very gradual; the average distance to one-meter depth was 15 m. The entire area was silt and mud. A small, shallow-sloping boat ramp was located 74 m east of the chain-link fence. The boat ramp was an old, wooden platform with carpet and was probably used to launch small non-motorized boats such as canoes. The Beer Sheva Park sites were sampled from March to June. All sites were surveyed three times with two additional samples for the boat ramp site on April 17th & May 16th. Only nighttime surveys were conducted.

Martha Washington Park. At Martha Washington Park, we surveyed one 100-m long transect along the shoreline (Figure 3). Substrate was composed predominately of boulders, cobble, and some gravel. Riprap was present along the entire shoreline except for two small coves that were each about 6 m long. Within the small coves, small gravel was the predominant substrate type. Sites were surveyed three times from late March to early May. All surveys were conducted at night. Snorkelers swam close to the shore along the 0.4 m depth contour. Because of the steep slope, we were able to survey from 0.0 to approximately 0.9 m depth.

WOODY DEBRIS AND OVERHANGING VEGETATION

In Lake Washington, natural shoreline structures such as woody debris and overhanging vegetation (OHV) are rare especially in the south end of the lake where juvenile Chinook salmon are concentrated. The addition of shoreline structure has often been suggested as a potential restoration project but little information is available on their use by juvenile Chinook salmon. To better understand the use of these rare shoreline structures by juvenile Chinook salmon we conducted two separate study elements: 1) a habitat manipulation experiment where we added small woody debris (SWD) and compared the use of the SWD to areas where no SWD was added; and 2) snorkel surveys of natural sites that had overhanging vegetation (OHV) and SWD. We focused our efforts on small woody debris (SWD; woody debris that is less than 10 cm in diameter) because large woody debris (LWD) is substantially more difficult to use in a habitat manipulation experiment and the few pieces of LWD that are present in south Lake Washington have few branches and thus have little structural complexity. Previous research in Lake

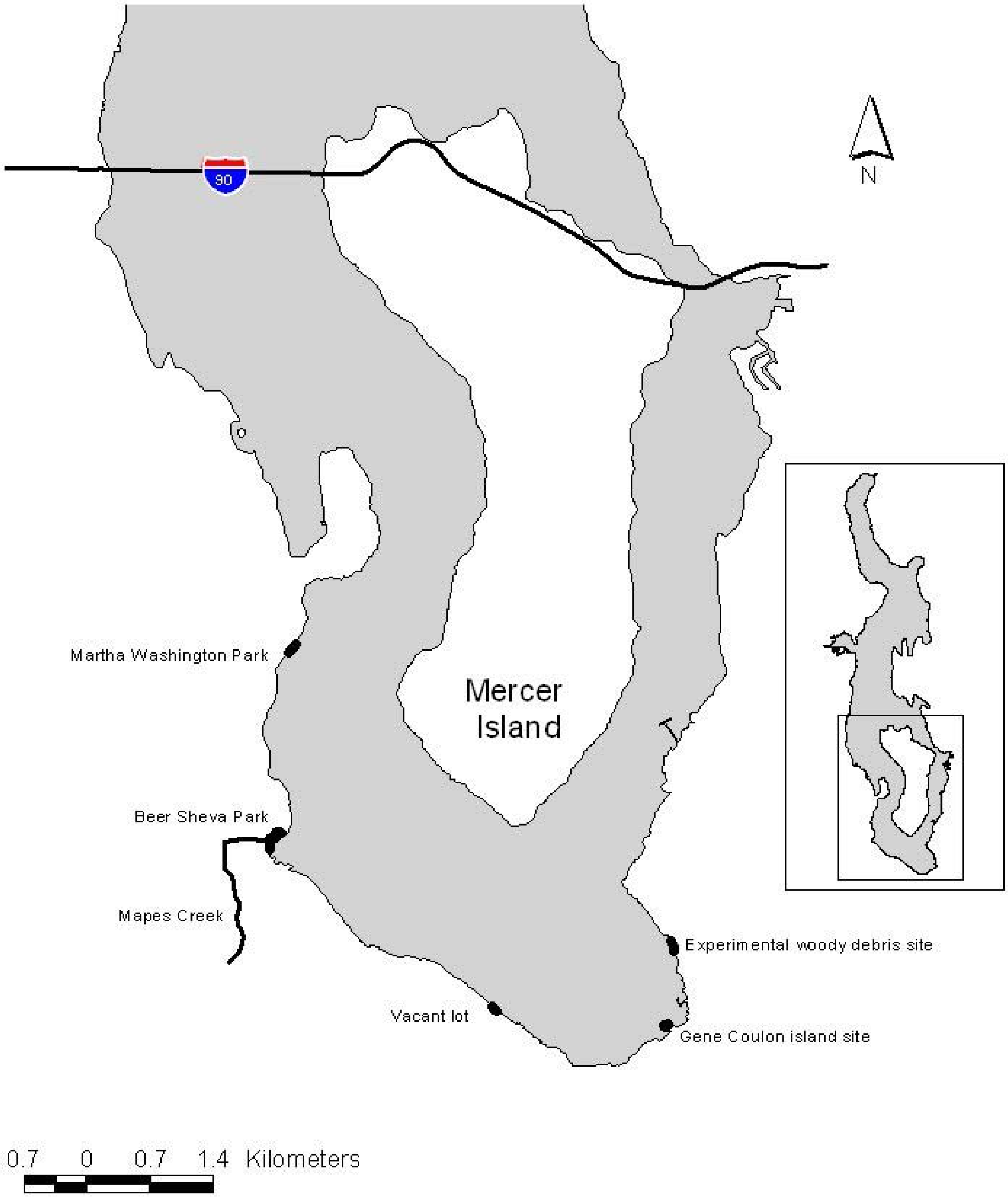


FIGURE 3.—Map of south Lake Washington displaying restoration monitoring sites (Beer Sheva Park and Martha Washington Park), natural overhanging vegetation/small woody debris (OHV/SWD) sites (vacant lot and Gene Coulon island site), and the experimental woody debris site. Mapes Creek, the proposed restoration site at Beer Sheva Park, is also shown.

PHOTO 2.-- Photo of the location of shoreline transects at Beer Sheva Park. The boat ramp transect is shown in the foreground. The northwest transect is located just past the third pier and is in the left part of the photo. The outlet of Mapes Creek is presently located in a culvert in the middle of this transect. The northwest transect is in the upper middle part of the photo. The photo was taken looking in a northeast direction.

Sammamish (Tabor and Piaskowski 2002) and in the Cedar River (R. Peters, unpublished data) has shown that juvenile Chinook salmon commonly use small woody debris. We defined overhanging vegetation as shoreline plants (live or dead) that overhang the water and are 1 m or less above the surface of the water. The vegetation must be dense enough to partially shade the water throughout the day. The vegetation must also overhang the water for at least 1 m from shore and the water depth must be at least 0.3 m at some point directly underneath the vegetation.

Woody debris experiment.– In 2001, habitat manipulation experiments were conducted in April and May in Gene Coulon Park to test the use of small woody debris by juvenile Chinook salmon. Overall results indicated that there was no difference in the abundance of Chinook salmon between shoreline sections with small woody debris and sections without woody debris. However, during the first early part of the experiment in early April, substantially more Chinook salmon were present in sections with SWD than in sections without SWD. Therefore, SWD may be an important habitat feature but only when the Chinook salmon are small in March and April. In 2002, we repeated the woody debris experiment in Gene Coulon Park, but began the experiment in early March and continued surveys until the beginning of June.

We used the same site in Gene Coulon Park used in 2001 (Figure 3). The shoreline was divided into seven 20-m shoreline sections: three with small woody debris and four without. Treatments were assigned systematically. The woody debris piles were 10 m long and located in the middle of the 20-m shoreline section. The woody debris consisted of tree branches and old Christmas trees placed in two rows parallel to shore. Each row was approximately 1 to 2 m wide. The rows were approximately 1.5 m apart, which allows room for a snorkeler to swim between them. Debris was placed along 0.3 and 0.7 m depth contours. The woody debris were tied together and anchored with sand bags and cement blocks. Snorkel surveys were conducted within each shoreline section. Daytime surveys were conducted weekly from March to the beginning of June. Two nighttime surveys were also conducted. Surveys were done along two depth contours, 0.4 and 0.7 m. During the day, Chinook salmon were active and often moved away from snorkelers. To get a more accurate count and insure that snorkelers did not push fish into an adjoining section, two snorkelers slowly swam toward each other from the outer edges of each shoreline section. After surveying each section, snorkelers compared notes on fish observed and adjusted fish counts to reduce the likelihood that fish were double counted. At night, shoreline sections could be surveyed by one snorkeler. Fish were inactive and usually did not react to the snorkeler. Occasionally, a Chinook salmon was startled but usually only swam away a short distance in any direction. Therefore, it was possible for a fish to have moved into an adjoining section, but we considered this number to be insignificant in comparison to the total number of fish observed.

Natural overhanging vegetation and small woody debris sites.-- Results in 2001 suggested that small juvenile Chinook salmon utilize sites with overhanging vegetation and small woody debris (OHV/SWD) but we were unable to document a significant difference between sites with these structures and those without. Too few sample dates may have limited our power to detect differences between the habitat types.

In 2002, we monitored two sites located in south Lake Washington, equidistant from the Cedar River mouth (approximately 1.2 to 1.3 km from the mouth), one on the west shore and the other on the southeast shore. The west shore site was located at a 54.7 m-long vacant lot (Figure 3). This site is one of the few large undeveloped locations along the west shore between the mouth of the Cedar River and Rainier Beach. The other site was at a small island in the southwest corner of Gene Coulon Park (Figure 3). We used an 86 m shoreline section along the east, south and west side of the island. We were unable to locate additional suitable sites that had OHV/SWD and were close enough to the Cedar River to have sufficient numbers of Chinook salmon. The two sites were surveyed weekly from March 3 to June 3. Between both sites there was a total of 29 day samples and 6 night samples. All surveys were snorkeled along a depth contour of 0.4 m.

Work in 2001 indicated OHV/SWD was primarily used during the day and avoided at night. In 2002, most surveys were conducted during the day but a few night surveys were also conducted for comparison. During the day, Chinook salmon were active and often moved away from snorkelers. To get a more accurate count and insure that snorkelers did not push fish into an adjoining section, two snorkelers slowly swam toward each other from the outer edges of each shoreline section. After surveying each section, snorkelers compared notes on fish observed and adjusted fish counts to reduce the likelihood that fish were double counted. At night, shoreline sections could be surveyed by one snorkeler. Fish were inactive and usually did not react to the snorkeler.

Transects within Gene Coulon island and the vacant lot were identified as one of three habitat types: open, OHV/SWD, or OHV. Transects categorized as “open” had no wood in the water and no overhanging vegetation along the shoreline. Transects categorized as “OHV/SWD” had large shrubs or small trees along the shoreline with branches hanging over the water. The SWD was mostly composed of large branches that had broken off from the shrubs or trees. The SWD also consisted of some branches that were still attached and hung down into the water. Transects categorized as “OHV” had large shoreline shrubs or small trees providing over hanging vegetation but no SWD was present in the water. At each shoreline section, we measured the total shoreline length as well as the length and width of each shoreline structure (Table 3). Additionally, information on substrate type and bank armoring was also collected.

Differences between transects were analyzed with a Friedman test, as recommended by Lehman (1975) to test nonparametric repeated measures data.

TABLE 3. Summary table of habitat types and characteristics at two SWD/OHV sites in south Lake Washington, February-June, 2002. Structure length (m) is the length of the shoreline that has either overhanging vegetation (OHV) or OHV and small woody debris (SWD) combined. Armoring (%) is the percent of the shoreline length that was armored with riprap.

Location Habitat type	Shoreline length (m)	Structure length (m)	Substrate	Armored (%)
Vacant lot				
Open	27.2	0.0	49% gravel, 45% cobble, 6% sand	0
OHV	15.0	4.7	40% gravel, 50% boulder, 10% cobble	67
OHV/SWD	12.5	6.5	40% gravel, 50% cobble, 10% sand	0
Gene Coulon island				
Open	37.0	0.0	42% gravel, 38% sand, 20% boulder	51
OHV	18.0	5.4	95% sand, 5% gravel	0
OHV/SWD	31.0	11.4	36% gravel, 55% cobble, 9% sand	61

TRIBUTARIES

We sampled areas in and around tributaries to determine the relative importance of the lower reach of tributaries, tributary deltas, and lake shoreline areas. Seventeen tributaries were surveyed, located in three major areas: south Lake Washington (including Mercer Island) (Figure 4), north Lake Washington (Figure 5), and south Lake Sammamish (Figure 6). In one tributary, Thornton Creek, we also surveyed a secondary tributary of that creek (Figure 5). We attempted to sample each Lake Washington tributary at least once in March, April, and May.
Lake Sammamish tributaries were surveyed twice, once in late April before juvenile Chinook salmon were released from the Issaquah Creek Hatchery and once in early June after the hatchery fish were released. Johns Creek was sampled biweekly from late February to early July. This creek was selected for further investigation because large numbers of juvenile Chinook salmon were observed in February.

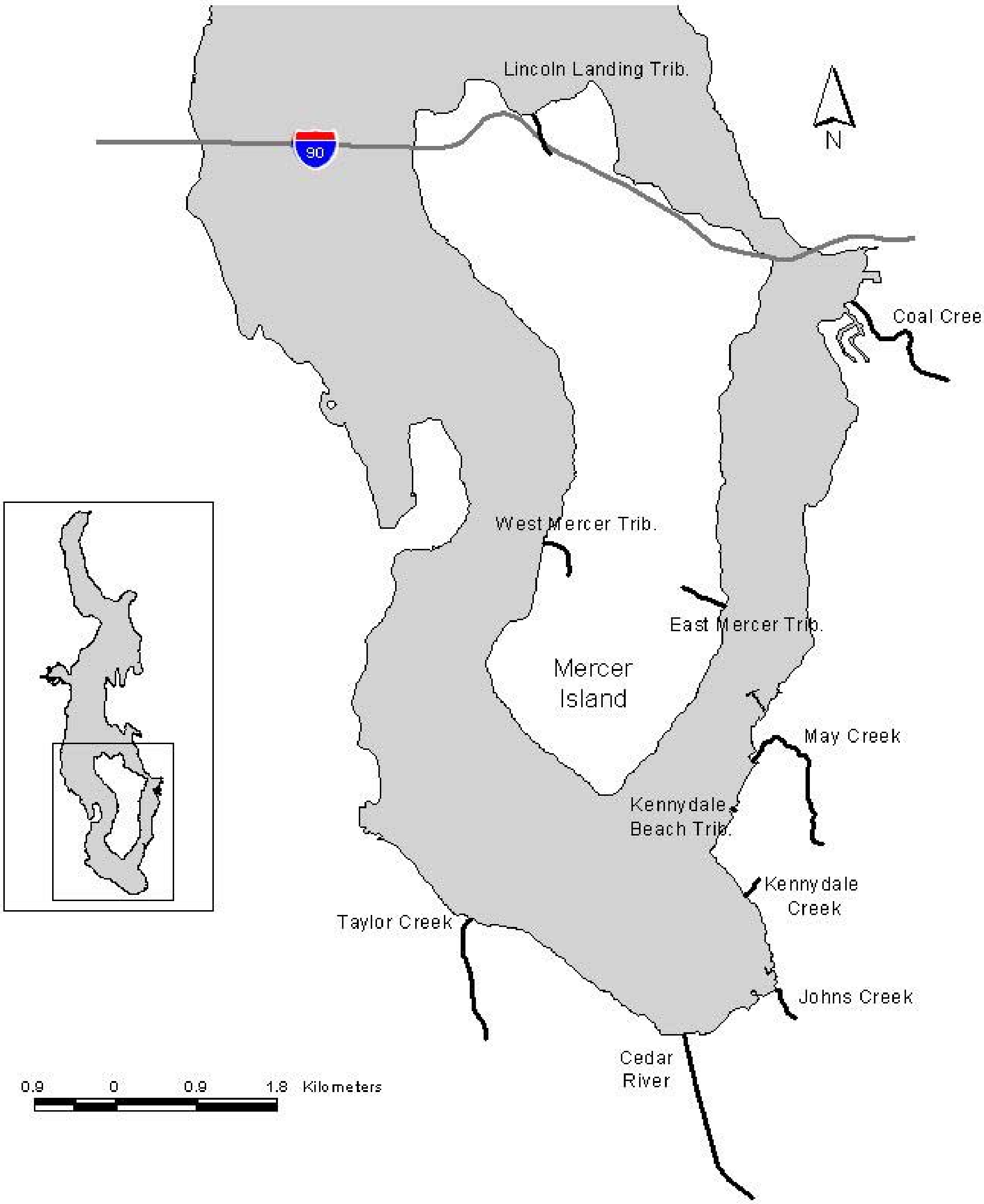


FIGURE 4.—Location of nine south Lake Washington tributaries studied to examine the use of nonnatal tributaries by juvenile Chinook salmon, March-June, 2002. The Cedar River, a major spawning tributary for Chinook salmon, is also shown.

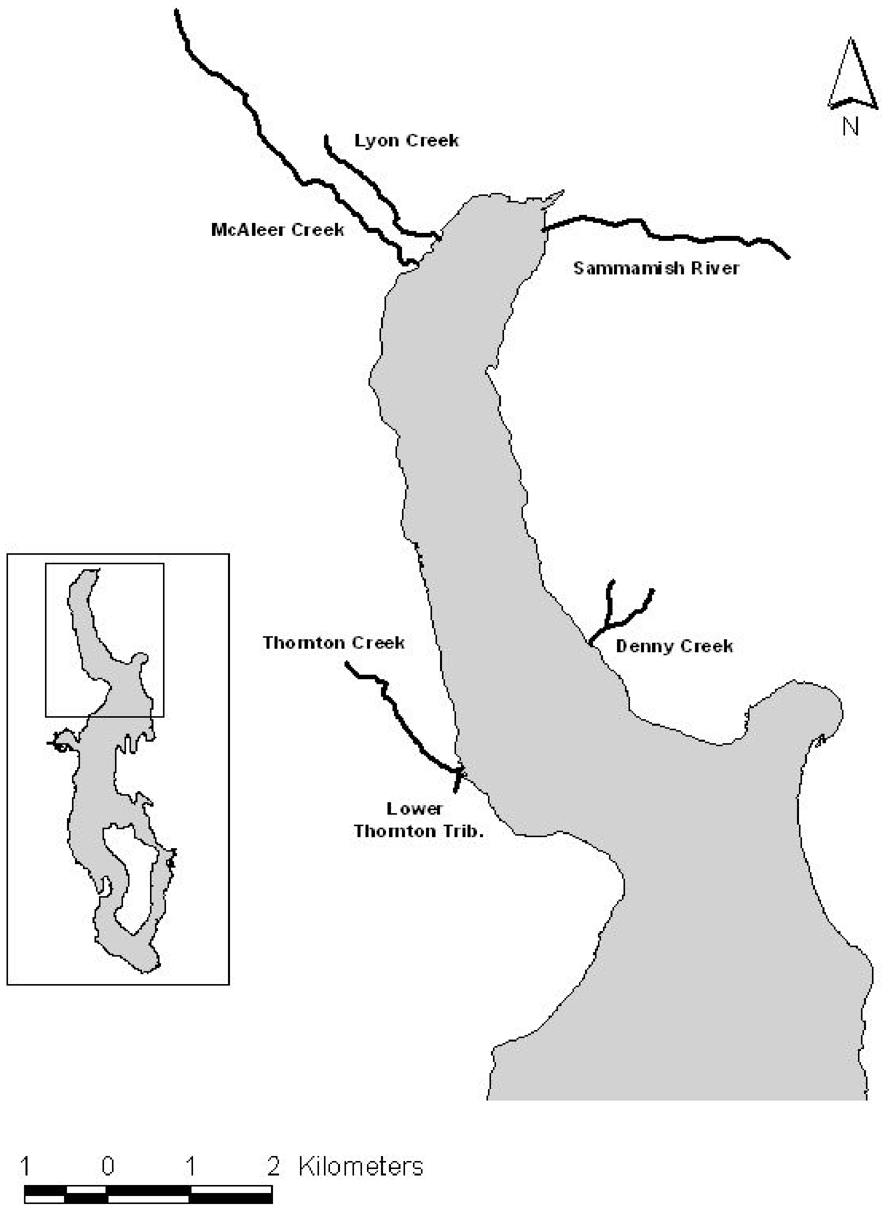


FIGURE 5.—Location of four north Lake Washington tributaries studied to examine the use of nonnatal tributaries by juvenile Chinook salmon, March-June, 2002. The Sammamish River, an important migratory corridor for juvenile Chinook salmon, is also shown.

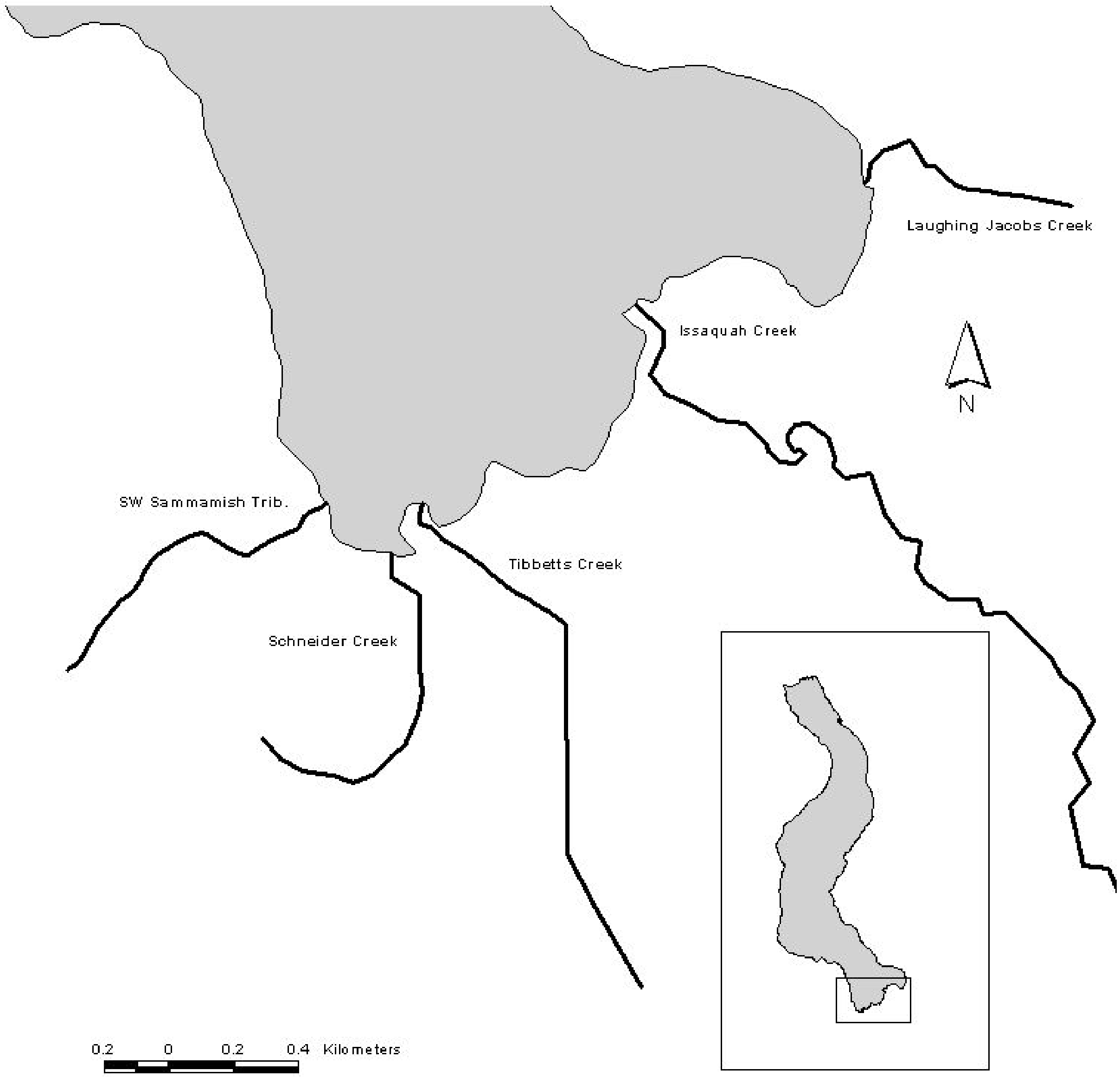


FIGURE 6.—Location of four south Lake Sammamish tributaries studied to examine the use of nonnatal tributaries by juvenile Chinook salmon, March-June, 2002. Issaquah Creek, a major spawning tributary and hatchery release site for Chinook salmon, is also shown.

At each tributary, we surveyed four general habitat types including: a lake reference site, delta area, convergence pool, and pools and glides within the tributary (Photo 3; Table 4). The reference site and delta were within the lake and the pools and glides and convergence pool were in the tributary itself. The reference site was a nearby lake shoreline site that appeared to have good quality habitat for juvenile Chinook salmon (i.e., gentle slope with small substrates). At these sites, we expected to observe juvenile Chinook salmon if they were present in that part of the lake. Two depth contours were surveyed, 0.4 and 0.7 m depth at the lake reference site. The reference site was either adjacent to the delta or a short distance away. In some cases, we used the same reference site for two or three tributaries. The delta was the location where the tributary emptied into the lake. Typically, there was a fluvial fan, which consisted primarily of fine substrates. We typically chose two transects within the delta, 0.4 and 0.7 m depth contours. Three transects were surveyed at some larger deltas (0.4, 0.5, and 0.7 m depth contours). At some small tributaries, where there was little or no delta present (all Mercer Island tributaries, Denny Creek, and SW Sammamish tributary), we used a 10-m-shoreline length (5 m on each side of the tributary) as the arbitrary delta area. At two tributaries, there was no clear-cut distinction where the stream ended. No surveys of the delta were conducted at these sites. Convergence pools were the downstream end of the tributary that backed up water from the lake (Photo 4) (Hawkins et al. 1993). The size of the convergence pool changed depending on lake level. Upstream of the convergence pool, we attempted to survey at least two or three pools or glides. At some tributaries, we were unable to survey any pools or glides because the stream was not accessible (i.e. culvert [East Mercer Tributary]or dense riparian vegetation [Kennydale Beach Tributary]) or there appeared to be an impassable barrier to juvenile Chinook salmon (West Mercer Tributary).

All surveys were only conducted at night except at Johns Creek where both day and night surveys were done. Sites were surveyed primarily by snorkeling. However, in some areas where snorkeling was difficult such as in shallow areas (e.g., < 0.2 m depth), surface observations were conducted by walking slowly along the stream bank. Heggenes et al. (1990) found that surface observations and snorkeling produced similar results for determining juvenile salmonid habitat use in locations with low water velocities and fine substrates. Because small juvenile Chinook salmon typically inhabit this type of habitat in the Cedar River (R. Peters, unpublished data) and in other river systems (Murphy et al. 1989), we felt surface observations would give reliable information and would be comparable to snorkeling observations. Surface observations were used primarily for shallow glides, pools, and convergence pools (reference and delta sites were always done through snorkel surveys). Additionally, we often conducted surface observations along the edges of riffles. After surface observations were completed, some fish were collected with small dip nets for species identification.

During each tributary survey, we measured water temperature (^oC) and turbidity (NTU) in the tributary and at the reference site along the lake shoreline. At the four tributaries (Johns Creek, Kennydale Creek, May Creek, and Taylor Creek) closest to the Cedar River, we also installed temperature loggers. An additional temperature logger was placed along the lake shoreline near each of the four tributaries.

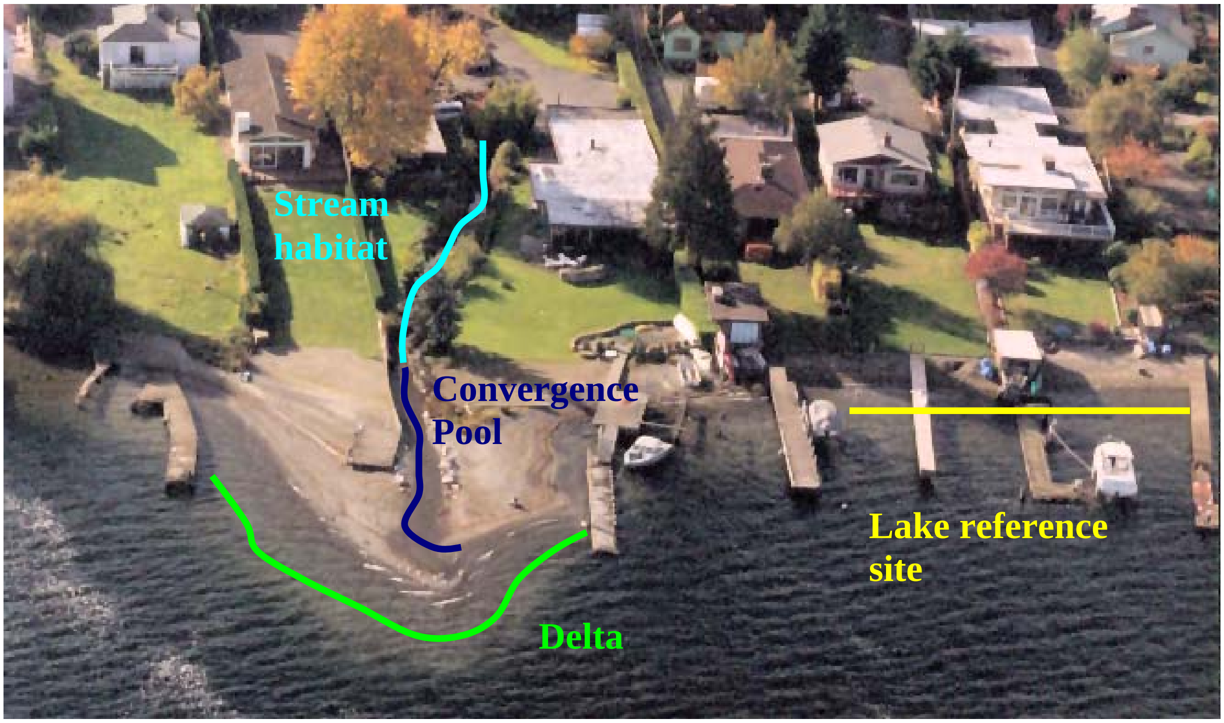


PHOTO 3.-- Aerial photo of Taylor Creek, showing an example of the approximate locations of habitats surveyed to assess the importance of tributaries. Upstream of the light blue line the stream is in a culvert and was not surveyed. Photo courtesy of Keith Kurko, Seattle Public Utilities.

PHOTO 4.-- Convergence pool of Johns Creek. The convergence pool is backed up water due to the level of the lake. The photo was taken in May when the convergence pool was at or close to its maximum size. Approximately 50 m beyond the bridge is Lake Washington.

TABLE 4. Number and length of transects used to survey tributary habitat in Lake Washington and Lake Sammamish, March-June, 2002. Reference site and delta transects were in the lake, while other habitats were in the tributary proper. The tributary study reach length includes the convergence pool, other pools, glides, and riffles. The length of the convergence pool was the length at the highest lake level. The length of riffles was not included in the table but would be the tributary study reach length minus the length of the convergence pool and pools and glides.

Area Shoreline Tributary	**Lake reference transects** Length (m)	**Delta transects** #	Length (m)	**Tributary study reach** Length (m)	**Convergence Pool** Length (m)	**Pool and Glide Habitats** #	Length (m)
South Lake Washington							
East							
Johns Cr.	40	0	--	259	133	5	91
Kennydale Cr.	50	2	27	61	7	3	5
Kennydale Beach Trib.	73	2	12	0	0	0	--
May Cr.	73	3	80	278	62	4	43
Coal Cr.	66	2	108	186	91	1	21
West							
Taylor Cr.	23	2	39	77	15	3	7
Mercer Island							
East Mercer Trib.	73	2	20	0	0	0	--
West Mercer Trib.	70	2	20	19	19	0	--
Lincoln Landing Trib.	42	2	20	53	0	4	10
North Lake Washington							
East							
Denny Cr.	49	2	20	81	9	4	13.6
West							
Lyon Cr.	71	3	74	136	50	2	20
McAleer Cr.	58	3	69	80	45	2	20
Thornton Cr.	48	2	81	127	30	4	53
Lower Thornton Trib.	48	0	--	38	13	1	22
South Lake Sammamish							
East							
Laughing Jacobs Cr.	41	2	44	228	31	4	25
West							
Tibbetts Cr.	199	2	24	203	79	6	87
Schnieder Cr.	199	2	21	194	83	10	72
SW Sammamish Trib.	199	2	20	126	7	2	10

Streamflow was measured once at each site. We tried to measure streamflow during baseline spring flows when the streamflow was not strongly influenced by a recent rain event. In medium and large tributaries, the streamflow was determined by measuring water velocities across the stream channel according to Timber-Fish-Wildlife (TFW) stream ambient monitoring methodology (Pleus 1999). At small tributaries, taking several water velocity readings was impractical and, therefore, we measured streamflow by placing a large bucket under a culvert or waterfall and measuring the volume of water in the bucket per amount of time.

Habitat surveys were conducted at each site. Survey procedures for tributary habitat (convergence pool and upstream habitat) were adapted from Pleus et al. (1999). Streams were delineated into habitat units, which were classified as either a pool, glide, or riffle. Habitat units also were categorized as primary or secondary units. Primary units spanned more than 50% of the wetted channel width, while secondary units covered less than 50%. Length and width were measured for each habitat unit. At pools and glides, we measured the maximum depth and the outlet depth. The percentage of the dominant and subdominant substrate types was visually estimated at each habitat unit. Stream gradient within each study reach was also estimated using a stadia rod and level. Habitat surveys of delta areas and lake reference sites were done similarly to habitat surveys of index sites.

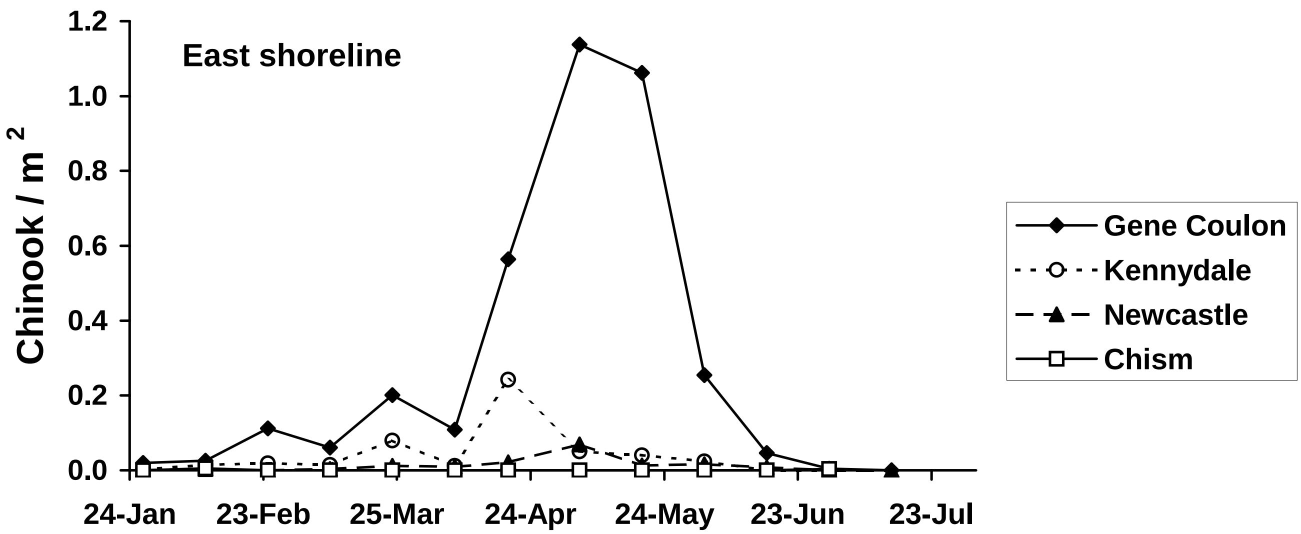
At Kennydale Creek (located in Gene Coulon Park, Figure 4), we conducted a preliminary diet analysis to determine if juvenile Chinook salmon at the delta area were foraging on prey items that came into the lake via the tributary. We compared the diet of Chinook salmon collected at the mouth of Kennydale Creek to those collected along the lake shoreline, approximately 150 m to the south of the tributary mouth. Fish were only sampled on one date (April 11). Juvenile Chinook salmon were collected at night with small dip nets. After capture, fish were anesthetized with MS-222 and the fork length was measured to be nearest mm. Stomach contents of fish were removed by gastric lavage. Stomach contents for each site were combined into one sample to simplify lab processing. They were put in plastic bags, placed on ice, and froze. In the laboratory, samples were thawed, examined under a dissecting scope, and divided into major prey taxa. Insects and crustaceans were identified to family or order, while other prey items were identified to major taxonomic groups. Prey groups were counted and then weighed. Each group was blotted by placing the sample on tissue paper for approximately 10 seconds. Prey groups were weighed to the nearest 0.001 g.

RESULTS

INDEX SITES

Juvenile Chinook salmon appeared to be concentrated in the south end of the lake throughout most of the sample period (Figure 7). The two southern-most sites (113th Street and Gene Coulon beach) had substantially higher densities (fish/m^2) of juvenile Chinook salmon from late January to early June than any other site. Densities at 113th Street were 1.8 to 17 times higher than the closest site on the west shoreline, Pritchard beach. Likewise, densities at Gene Coulon beach were 1.6 to 26 times higher than the closest site on the east shoreline, Kennydale beach. Peak abundance at both southern-most sites occurred in May. The second most southerly site on both shorelines (Pritchard beach and Kennydale beach) constantly had higher densities than the further north sites. On most nights, the most northerly site had the lowest density of Chinook salmon. Only two Chinook salmon were ever observed at Chism Park beach, the furthest north site on the east shoreline. We also calculated the density of Chinook salmon per shoreline length; trends were similar to density per area calculations (fish/m^2). Overall, the abundance (fish/m^2) of Chinook salmon was negatively related to the shoreline distance from the mouth of the Cedar River to each site (Figure 8). The data were best explained with a logarithmic function (abundance =-0.13ln(distance) + 0.33; r^2 = 0.79; Figure 8).

From January to the beginning of June, there was no apparent difference in juvenile Chinook salmon distribution between the east and west shorelines; however, the overall densities were higher on the east shoreline from mid-April to mid-May, due in large part to the high densities at Gene Coulon Park (Figure 7). Comparison of the densities of the two southern sites (west, 113th Street and east, Gene Coulon beach) indicated there was no statistical difference (Wilcoxon test, Z = 0.59, P = 0.95). Of the next two sites, Pritchard Beach site (west shore) had a higher density than the Kennydale beach site (east shore) on 8 of 12 nights surveyed; however the differences were not significant (Wilcoxon test, Z = -1.6, P = 0.12). Substantially more Chinook salmon were observed on the west shoreline on June 18 and June 30; however, the differences were only significant on June 30 (Mann-Whitney U tests; June 18, P = 0.14; June 30, P = 0.048). The last survey date was July 14 and only one Chinook salmon was observed out of five sites surveyed (three west and two east shoreline sites). No Chinook salmon were seen at either Gene Coulon Park or 113th St.



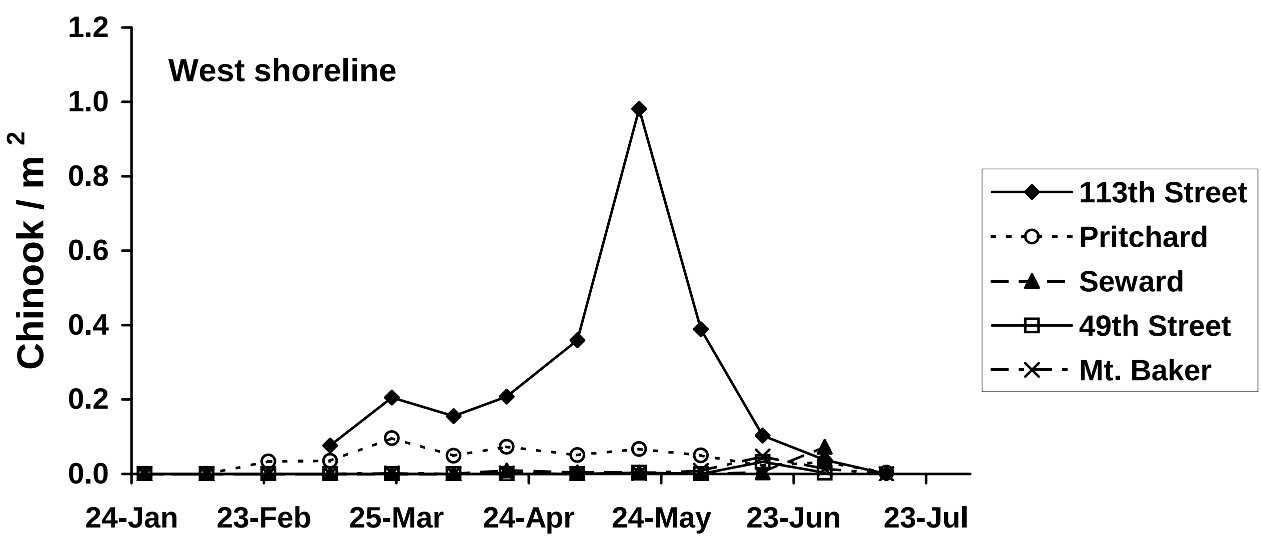


FIGURE 7. Chinook salmon density (number/m^2) at four east shoreline sites and five west shoreline sites in south Lake Washington, 2002. Data were collected through nighttime snorkel surveys along two depth contours; 0.4 and 0.7 m.

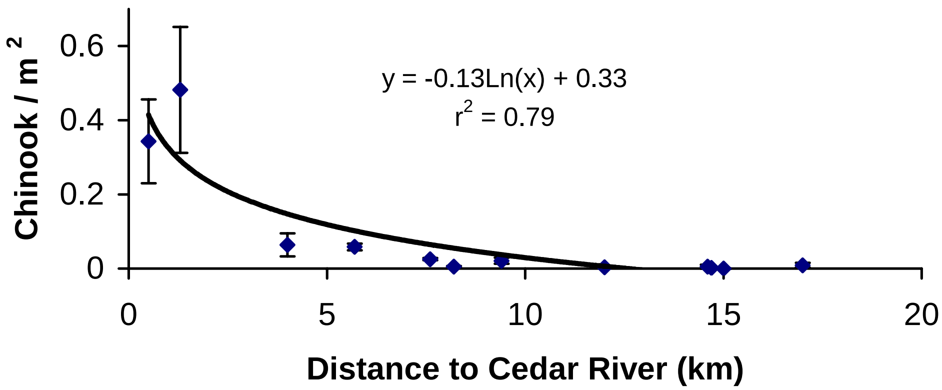


FIGURE 8. Relationship between the mean juvenile Chinook salmon density (±1 SE, n = 7) and the shoreline distance to the mouth of the Cedar River in south Lake Washington, 2002. The density represents the mean from March 24 to June 16, 2002. Sites include west and east shorelines and Mercer Island sites (includes distance from Coleman Point to South Point [see Figure 1]).

Juvenile Chinook salmon were observed at Mercer Island sites every night surveyed from late March to the middle of June (Figure 9). There were more juvenile Chinook salmon at the East Mercer Island site than the other two Mercer Island sites combined, and differences were statistically significant (Friedman test = 11.1, P = 0.004). In general, the density of Chinook salmon on Mercer Island was similar to nearby sites on the west and east shorelines. The East Mercer Island site was not significantly different than the two closest sites on the east shoreline (Wilcoxon tests, Newcastle, Z = 1.0, P = 0.31; Kennydale, Z = -0.9, P = 0.40). The density of Chinook salmon at the West Mercer Island site was significantly lower than the Pritchard Beach site (Wilcoxon test, Z = -2.4, P = 0.018); however, Pritchard Beach is 2.5 km closer to the Cedar River than the West Mercer site. Densities at the West Mercer site and Seward Park beach site (3.8 km further away from the Cedar River than the West Mercer site) were similar (Wilcoxon test, Z = -4.1, P = 0.69). There was no difference between the Luther Burbank Park site and the Chism Park site (Wilcoxon test, Z = -1.4, P = 0.16), which are a similar distance away from the Cedar River.

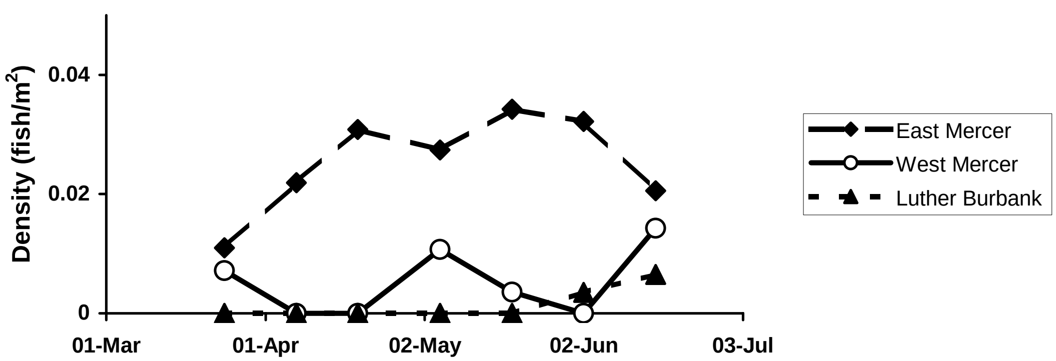


FIGURE 9. Chinook salmon density (fish/m^2) at three Mercer Island sites, Lake Washington, 2002. Data were collected through nighttime snorkel surveys along two depth contours; 0.4 and 0.7 m.

RESTORATION SITES

<u>*Seward Park.*</u> Sites were surveyed nine times each between March 18 and July 10. All surveys were conducted at nighttime. Combined, only 43 juvenile Chinook salmon were observed, with over 50% (n=24) found at the southeast sites (sites 1 and 2). With the exception of March 19, the southeast sites had the highest number of juveniles per 100-meters on all surveys (Figure 10). Of the 24 Chinook salmon observed in the southeast sites, 21 were present at site 1, the southern most site (Figure 2). Only seven juvenile Chinook salmon (two at site 3a and five at 3b) were observed at the restoration site during the study period. Because of the small sample sizes, it is difficult to make any meaningful comparison between the two substrate types (sites 3a and 3b).

A comparison between 2001 and 2002 for the months of April, May, and June indicated more Chinook salmon were present in 2001 than 2002 in April and May, but numbers were similar in June (Figure 11). A comparison of site 3 between 2001 and 2002 showed no evidence of increased juvenile Chinook salmon use of the restoration site relative to the other Seward Park sites (Figure 12). The ratio of Chinook salmon at site 3 to the other sites combined was 0.45:1 in 2001 and 0.30:1 in 2002 (Figure 13).

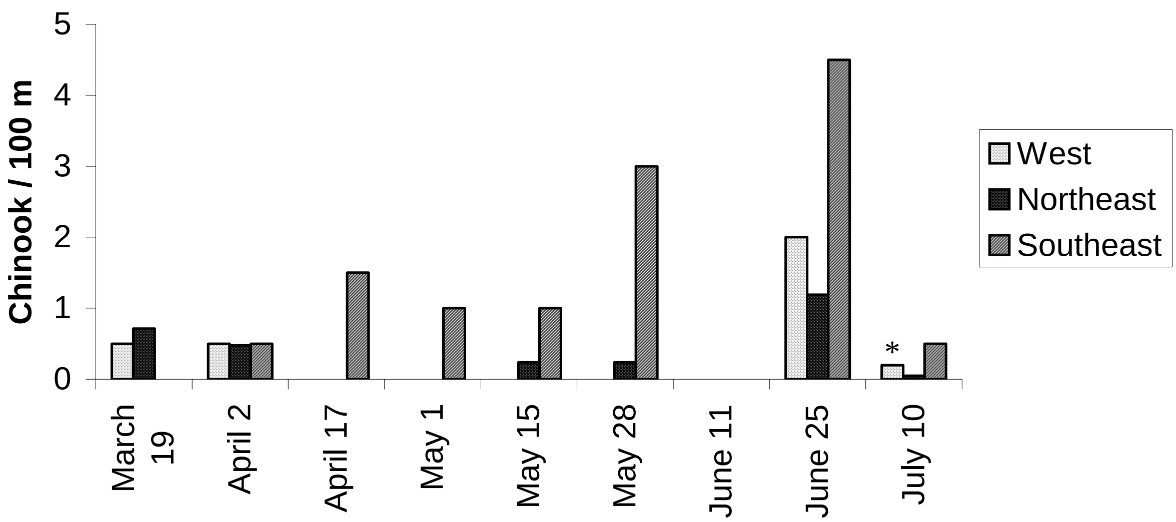


FIGURE 10. Number of juvenile Chinook salmon (number / 100 m) observed at night along three shoreline areas of Seward Park, south Lake Washington, 2002. *Chinook numbers for West & Northeast sites for July 10th were incomplete counts and the total number was based on other sites surveyed on that date.

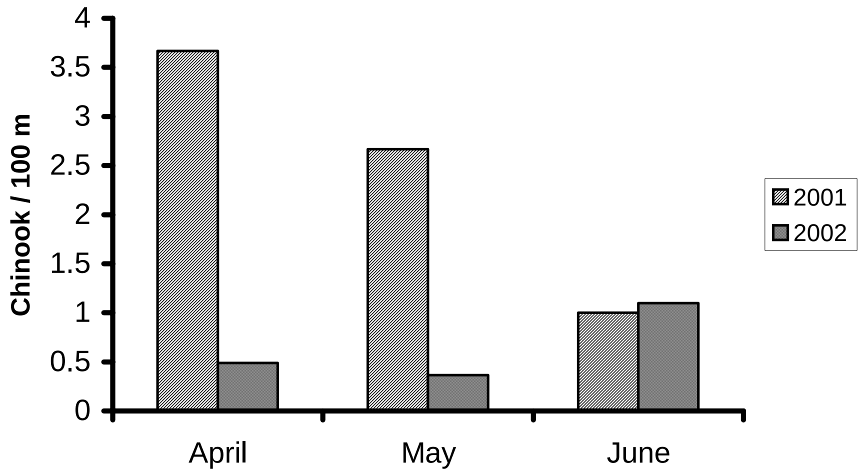


FIGURE 11. Monthly abundance (mean number observed per 100 m of shoreline) of juvenile Chinook salmon observed during night snorkel surveys of six shoreline sites in Seward Park, south Lake Washington.

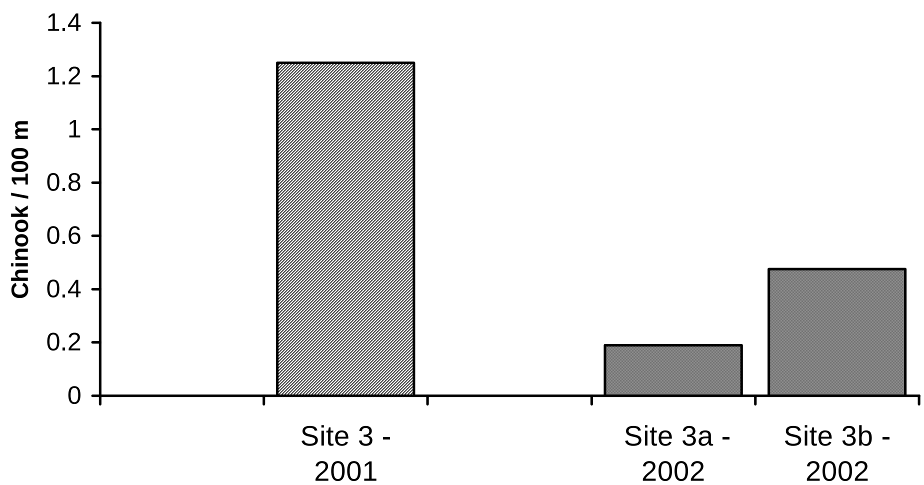


FIGURE 12. Abundance (mean number observed per 100 m of shoreline) of juvenile Chinook salmon at the restoration site (site 3), April – June 2001 and 2002. Site 3 is located on the northeast side of Seward Park, south Lake Washington. Site 3a is the southern section that received the large gravel while site 3b is the northern section that received the small gravel.

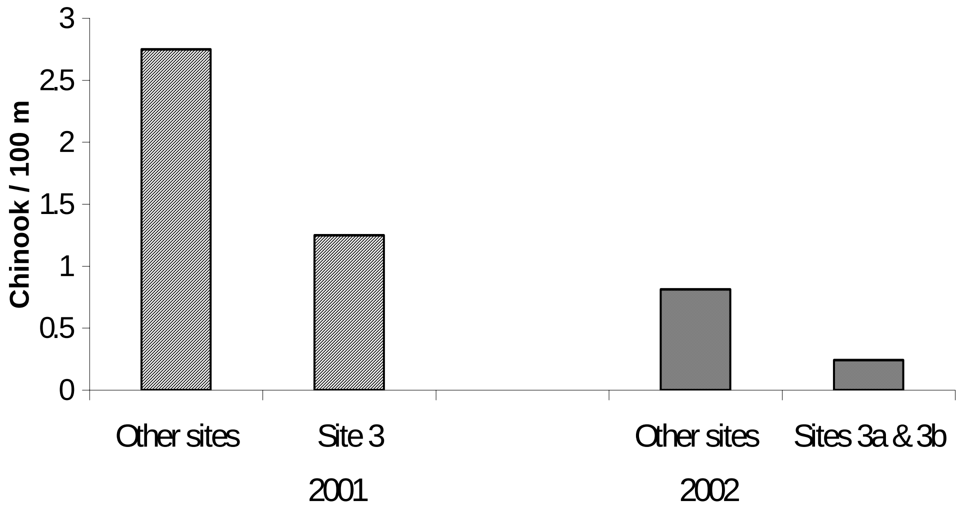


FIGURE 13. Abundance (mean number observed per 100 m of shoreline) of juvenile Chinook salmon at site 3 and other sites (sites 1,2,4,5,6 combined) in 2001 and in 2002, March-July, Seward Park, south Lake Washington. Data were collected through night snorkel surveys.

Additionally, the restoration sites (sites 3a and 3b) had a lower overall abundance of other fish (e.g., prickly sculpin (*Cottus asper*), threespine stickleback (*Gasterosteus aculeatus*), and yellow perch (*Perca flavescens*) than other Seward Park sites. Because the substrate at the restoration site had only been in place a few months, the abundance of fish and their prey (e.g., benthic invertebrates) was probably lower than normal. It will probably take additional time for many species to completely recolonize these sites. The substrate at the restoration site was noticeably cleaner than the other sites. Adult peamouth (*Mylocheilus caurinus*) did, however, appear to prefer the restoration site. Presumably, peamouth preferred the restorations site's clean substrates for spawning. Ninety-nine percent of all adult peamouth were observed on May 1. They were close to shore and appeared to be spawning. In 2001, the highest density of adult peamouth was observed in Site 4; whereas in 2002, the highest density was observed at the restoration sites (sites 3a and 3b) and only one peamouth was observed at Site 4. Both coarse and fine substrate sections appeared to be used extensively by spawning peamouth.

Beer Sheva Park. The nearshore area of Beer Sheva Park was surveyed between March 25 and June 25 (Table 5). On the three dates in which all three transects were surveyed, the density of juvenile Chinook salmon was always highest at the boat ramp site. The highest abundance ever observed at Beer Sheva Park (82 juvenile Chinook salmon) was at the boat ramp site on May 16. In three surveys of the northeast site, 13 juvenile Chinook salmon were observed and all were located on an old carpeted boat ramp at the corner of the transect. The two northern sites were not sampled on April 17 and May 16 due to high turbidity and water quality concerns.

TABLE 5. Abundance (number of fish/100 m shoreline length) of juvenile Chinook salmon along three transects within Beer Sheva Park, Lake Washington, March-June, 2002. ND = no data.

	# of Chinook / 100 m		
Sampling Date	Boat Ramp	Northwest	Northeast
March 25	12.3	5.2	3.9
April 17	25.6	ND	ND
April 23	12.3	0.0	6.25
May 16	126.2	ND	ND
June 4	6.2	ND	ND
June 25	15.4	3.4	0.0

Martha Washington Park. The Martha Washington Park surveys were conducted on March 20, April 10, and May 1 . Only two juvenile Chinook salmon were observed in three surveys. In addition, two juvenile coho salmon (*O. kisutch*) were seen on May 1st.

WOODY DEBRIS AND OVERHANGING VEGETATION

Woody debris experiment.– The experimental woody debris site was surveyed weekly from March 5 to June 6. A total of 14 surveys were conducted. The overall abundance of Chinook salmon varied greatly from 0 to 240 fish. On four dates, no Chinook salmon were observed in any of the seven shoreline sections and on another date, only one Chinook salmon was observed. Chinook salmon were abundant at the study site on one date in early March and on three dates between late April and late May (Figure 14). In March and April, several storms occurred which may have altered the distribution of juvenile Chinook salmon.

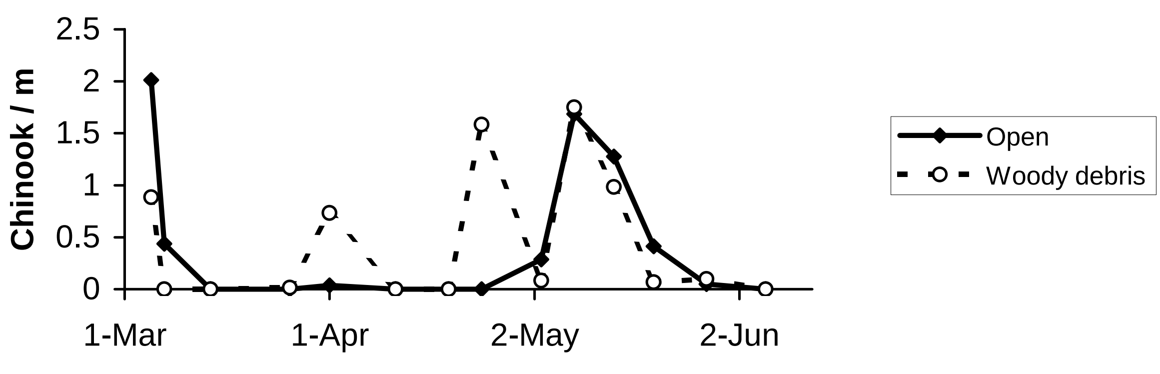


FIGURE 14. Daytime abundance (number of Chinook/m of shoreline) of juvenile Chinook salmon in experimental woody debris shoreline sections and adjacent open (control) sections, Gene Coulon Park, south Lake Washington, March-June, 2002. Abundance is the mean of three woody debris and four open shoreline sections. Each shoreline section was 20-m long.

In general, Chinook salmon abundance decreased from northern to southern shoreline sections. Ninety percent of the total number of Chinook salmon observed were at the four northern most shoreline sections; whereas, only 10% were at the three south shoreline sections (Figure 15). The lowest number of Chinook salmon observed was at the southern most shoreline section and highest number observed was at the northern most shoreline section. In 2001, a similar trend was observed at this location. The substrate and slope are similar along this shoreline and it is unclear why Chinook salmon prefer the north part over the south part. One possibility is that the north sites are closer to a pier which may provide overhead cover if needed.

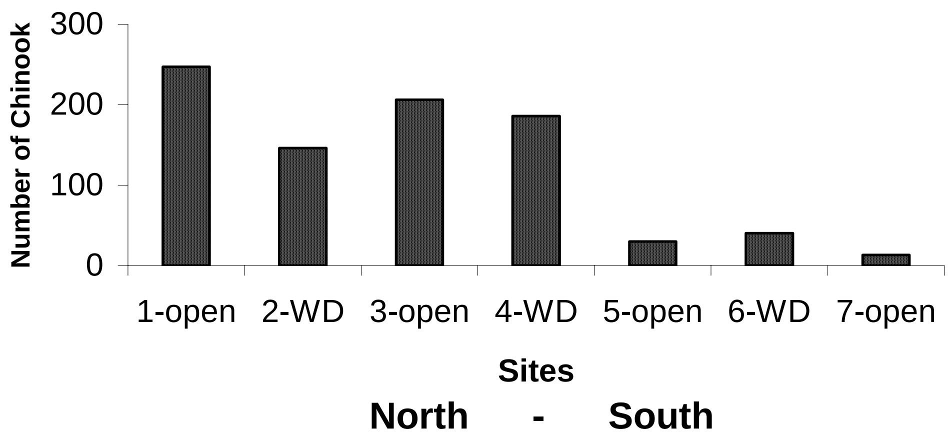


FIGURE 15. Total number of juvenile Chinook salmon observed at experimental woody debris sites (WD) and open or control sites, Gene Coulon Park, south Lake Washington. Sites were surveyed 14 times each from March to June, 2002. Sites are arranged from north to south.

Because the abundance of Chinook salmon varied greatly between north and south shoreline sections, we compared each woody debris section to an adjacent open shoreline section. Comparisons were done with a series of Wilcoxon tests. Analyses only included dates when at least one Chinook salmon was present at the sites compared. There was no significant difference found between any pair of shoreline sections.

Almost all Chinook salmon observed in April were present in the woody debris piles (Figure 16); however, on two of the four surveys, no Chinook salmon were observed in any shoreline section. On April 24, Chinook salmon were present in all three woody debris sections; whereas they were not observed in any of the open sections (Figure 16). In March and May, most Chinook salmon were present in the open shoreline sections. When Chinook salmon were observed at the woody debris sections they usually were active and located near the outside edge of the woody debris pile in 0.4 to 1.0 m deep water. Occasionally, we would observe a group of fish that were inactive, in 0.3-0.5 m deep water, and located directly under woody debris.

Night surveys were conducted on two dates (March 26 and May 17). Similar to 2001 observations, Chinook salmon were scattered along the shore, close to the bottom, and present at every shoreline section. In woody debris sections, they were either located on the outside edge of the woody debris or between the woody debris pile and the shoreline. Chinook salmon were rarely located directly under the woody debris. The overall mean abundance of Chinook salmon was the same between woody debris and open shoreline sections (mean, 0.107 Chinook / m of shoreline).

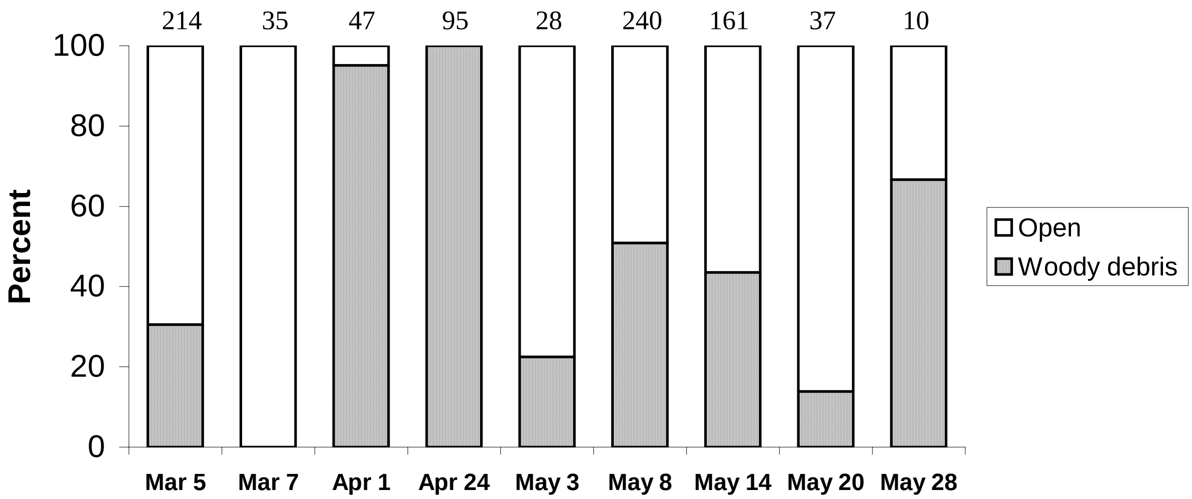


FIGURE 16. Ratio of the shoreline abundance (fish/m) of juvenile Chinook salmon present in experimental woody debris sites to those present in adjacent open (control) sites, Gene Coulon Park, south Lake Washington, March-June, 2002. The figure only includes dates when at least ten juvenile Chinook salmon were observed. All surveys were conducted during the daytime. The numbers on top of the bars indicate the total number of juvenile Chinook observed on that date.

Natural overhanging vegetation and small woody debris sites.—Daytime surveys at the Gene Coulon island were conducted on 15 occasions from March 5 to June 3. No fish were seen during the last three surveys after May 15. Combined, 505 juvenile Chinook salmon were observed. Between March 5 and May 10, the abundance was significantly different between habitat sections (Freidman test = 11.9, P = 0.003). On 9 of 12 dates during this period, the majority of juvenile Chinook salmon were located in the OHV/SWD habitat type (Figure 17). The highest abundance was 5.5 fish/m of shoreline, and occurred at the OHV/SWD type on March 5 (Figure 18). Overall, 80% of the Chinook salmon (n=405) were observed in the OHV/SWD habitat (Photo 5). Most of the remaining fish (n=77 or 15%) were found within the OHV habitat type. Chinook salmon seen in open habitat made up only 5% of the total number of Chinook salmon observed. Of the total fish seen in the open habitat type (n=23), 20 were seen schooling in the shade of a cut bank on April 23rd.

Results of daytime surveys at the vacant lot site were similar to results from the Gene Coulon island. Surveys were conducted on 14 occasions between March and June. A total of 618 juvenile Chinook salmon were counted for all surveys. Overall, the majority of juvenile Chinook salmon (n=544, 88%) were located in the OHV/SWD habitat type (Photo 6). The highest abundance was 12.0 fish/m of shoreline and occurred at the OHV/SWD transect on March 21 (Figure 19). Most of the remaining (n=65, 11%) fish were found within the open habitat type. Chinook salmon seen in the OHV habitat made up only 1% of the total number observed. Between March 13 and May 10, the abundance was significantly different between habitat sections (Freidman test = 7.4, P = 0.025). On 8 of 10 survey dates during this period, all of the Chinook salmon were in the OHV/SWD habitat section (Figure 20). Overall, 91% of the Chinook salmon were in the OHV/SWD habitat section; whereas, after May 10, only 7% were in that section. After May 10, few fish were observed and there was no apparent difference between habitat sections.

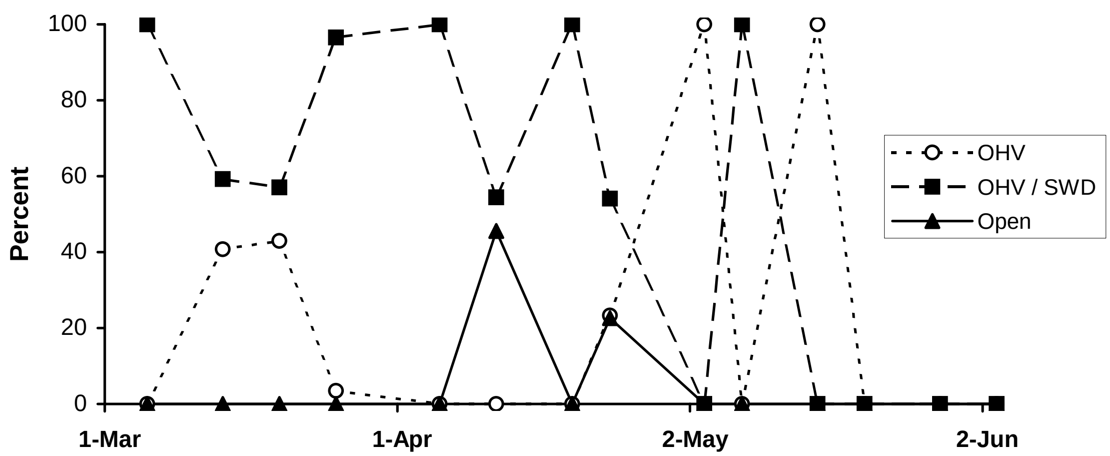


FIGURE 17. Percent of juvenile Chinook salmon among three habitat types at the Gene Coulon Island site, south Lake Washington, 2002. All surveys were conducted during the daytime. OHV = overhanging vegetation, SWD = small woody debris.

PHOTO 5.-- Overhanging vegetation and small woody debris (OHV/SWD) at the Gene Coulon island site. The structure is located to the far left and far right part of the photo. Large numbers of Chinook salmon were often present within these structures in March and April, 2003.

PHOTO 6.-- Group of juvenile Chinook salmon within small woody debris (SWD) at the vacant lot site. Both overhanging vegetation (OHV) and SWD were present at this location. Large numbers of Chinook salmon were often present within this structure from March to May, 2003.

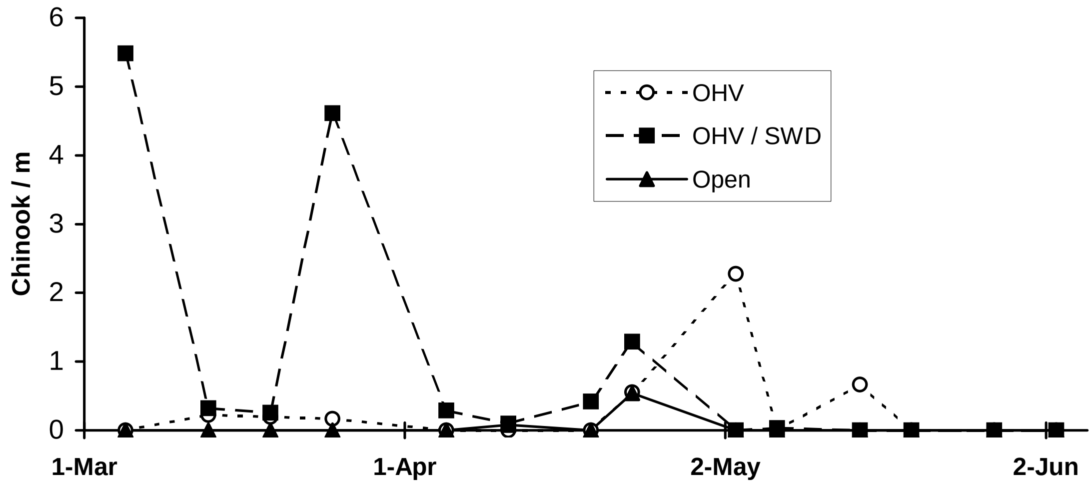


FIGURE 18. Abundance (# of Chinook/m of shoreline) of juvenile Chinook salmon among three habitat types at the Gene Coulon island site, south Lake Washington, 2002. All surveys were conducted during the daytime. OHV = overhanging vegetation, SWD = small woody debris.

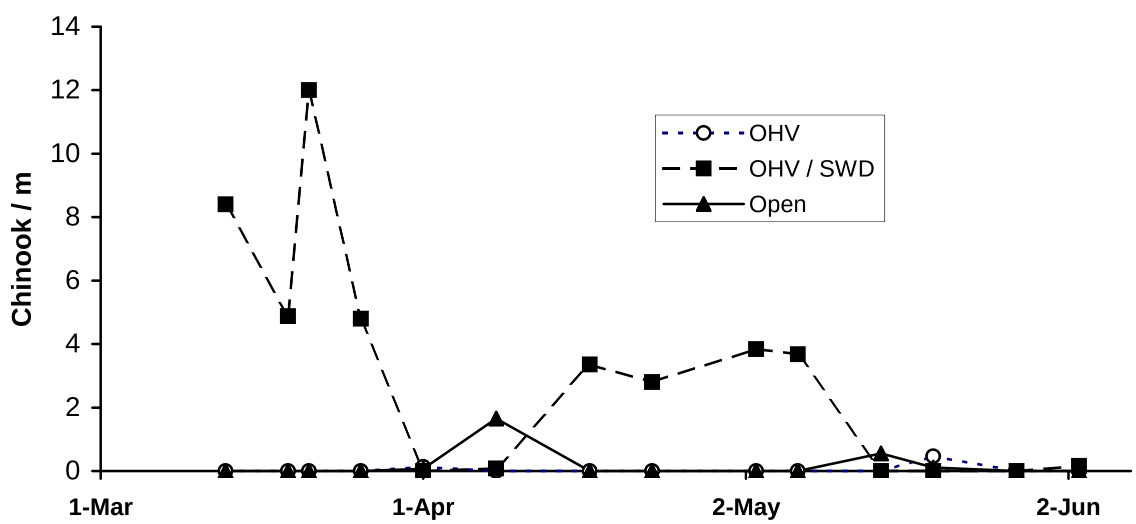


FIGURE 19. Abundance (# of Chinook/m of shoreline) of juvenile Chinook salmon among three habitat types at the vacant lot site, south Lake Washington, 2002. All surveys were conducted during the daytime. OHV = overhanging vegetation, SWD = small woody debris.

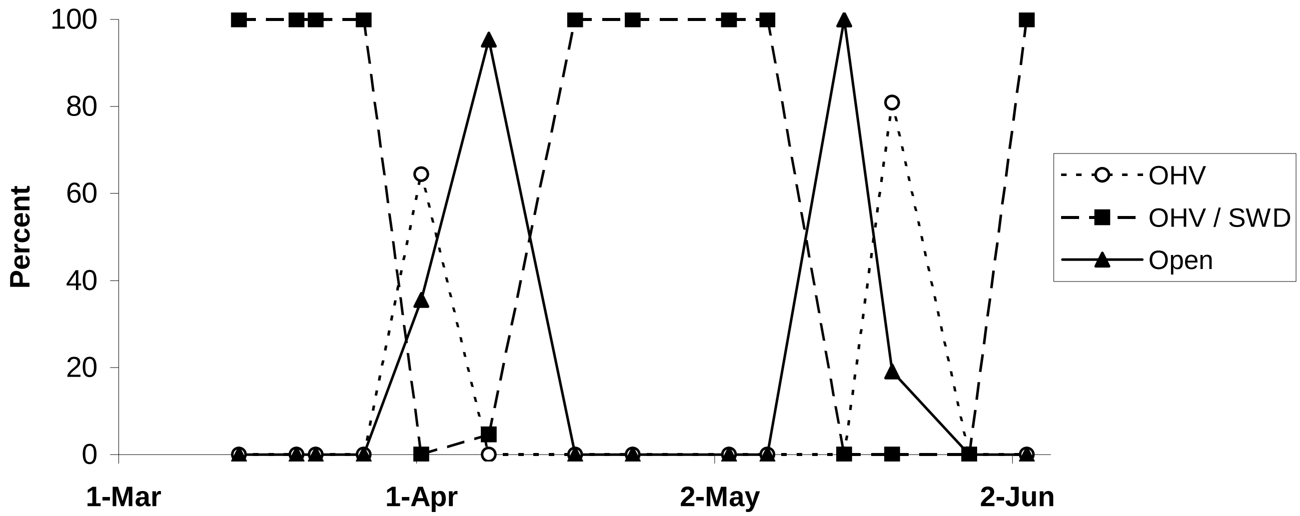


FIGURE 20. Percent of juvenile Chinook salmon among three habitat types at the vacant lot site, south Lake Washington, 2002. All surveys were conducted during the daytime. OHV = overhanging vegetation, SWD = small woody debris.

We conducted three nighttime Gene Coulon island surveys with a total of 325 juvenile Chinook salmon counted among: March 5 (n=213), March 18 (n=58), and May 16 (n=54). Nighttime surveys at the vacant lot site were also conducted on three dates. A total of 88 juvenile Chinook salmon observed; March 18 (n=26), March 26 (n=32), and May 16 (n=30). Overall, there was no apparent difference in juvenile Chinook salmon abundance between shoreline sections with or without shoreline vegetation (Figure 21).

During the day, Chinook salmon were grouped together and concentrated in one or two of the shoreline sections. In contrast, at night, Chinook salmon were dispersed and individuals were present in all shoreline sections. Also, during the day Chinook salmon were usually closely associated with the OHV or WD, whereas at night, they were always at least a few meters away from the structures. In general, the nighttime distribution appeared to be related to substrate type, similar to what we observed in 2001 (Tabor and Piaskowski, 2002). Chinook appeared to select sand and small gravel substrates. For example, at Gene Coulon island site, large numbers of Chinook salmon were observed on two occasions at the OHV site, which had the best sandy beach of the three shoreline sections.

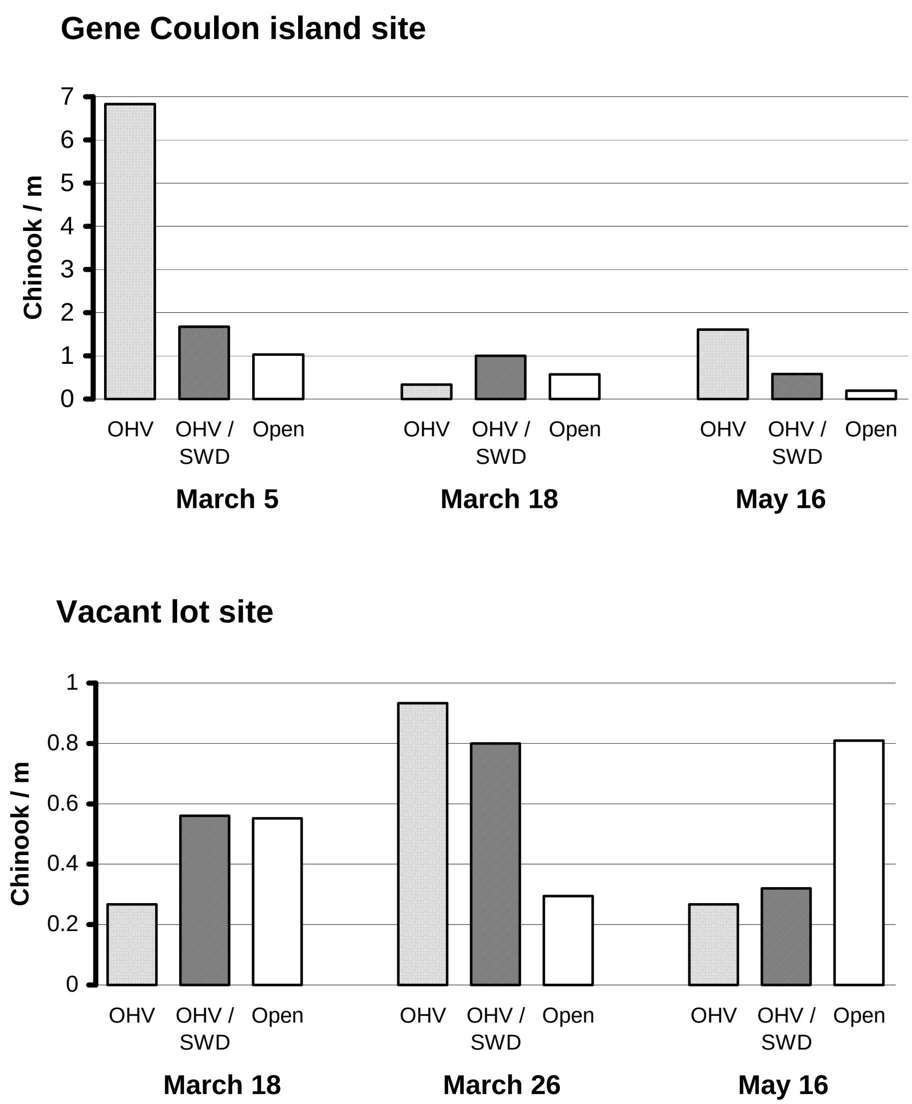


FIGURE 21. Nighttime abundance (number per meter of shoreline) of juvenile Chinook salmon along three habitat types at the Gene Coulon island site and vacant lot site, south Lake Washington, 2002. OHV = overhanging vegetation, SWD = small woody debris.

TRIBUTARIES

Seventeen tributaries were surveyed. Tributary conditions varied greatly from small, high gradient tributaries such as the Kennydale Beach Tributary and SW Sammamish Tributary to large, low gradient streams such as May Creek, Coal Creek, and Thornton Creek (Table 6). Streamflow ranged from 0.04 cfs at Kennydale Beach tributary to 18.5 cfs at May Creek. The approximate size of the delta also varied greatly from a few square meters at each of the Mercer Island tributaries to approximately 3,600 m^2 at Thornton Creek.

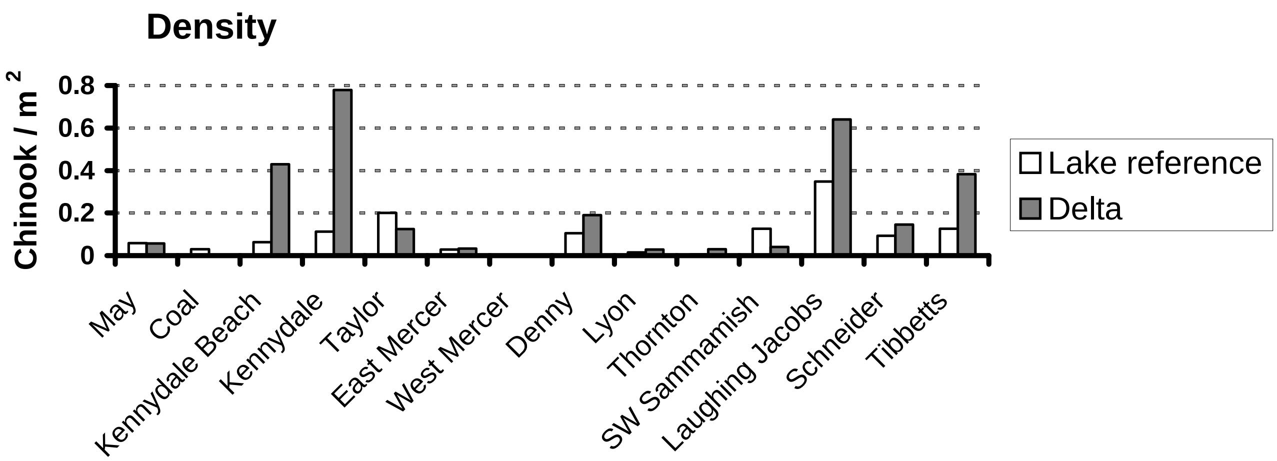
TABLE 6. Habitat measurements of several Lake Washington and Lake Sammamish tributaries, March-June, 2002. Measurements represent only the study reach in the lower section of each tributary. At some low gradient streams, we had difficulty obtaining an accurate gradient measurement; those streams were given a gradient of < 1 %. The delta area is the approximate area of fine sediments at the mouth of the tributary.

Area Shoreline Tributary	**Streamflow** (cfs)	**Gradient** (%)	**Mean Width** (m)	**Max. depth** (m)	**Armored banks**	**Delta area** (m^2)
South Lake Washington						
East						
Johns Cr.	0.80	0.6	4.96	1.10	yes	--
Kennydale Creek	0.52	5.9	1.27	0.44	no	93
Kennydale Beach Trib.	0.04	14.4	--	--	--	105
May Cr.	18.47	0.4	4.3	1.20	yes	2,160
Coal Cr.	9.15	0.3	5.84	0.60	yes	3,500
West						
Taylor Cr.	0.59	1.8	1.62	0.90	yes	722
Mercer Island						
East Mercer Trib.	0.13	--	--	--	--	15
West Mercer Trib.	0.16	< 1	2.65	0.48	yes	6
Lincoln Landing Trib.	0.15	6.9	0.97	0.30	no	5
North Lake Washington						
East						
Denny Cr.	0.76	3.0	2.33	0.48	no	6
West						
Lyons Cr.	3.13	0.3	3.46	0.80	yes	1,350
McAleer Cr.	11.46	< 1	4.11	1.40	yes	810
Thornton Cr.	7.74	1.7	4.14	1.60	yes	3,600
Lower Thornton Trib.	0.11	< 1	11.36	1.50	yes	--
South Lake Sammamish						
East						
Laughing Jacobs Cr.	2.84	1.4	2.46	0.50	no	404
West						
Tibbetts Cr.	6.45	< 1	5.25	1.70	no	1,100
Schnieder Cr.	0.86	< 1	1.83	0.80	no	235
SW Sammamish Trib.	0.11	5.1	1.13	0.52	no	6

The abundance of Chinook salmon in delta areas and lake reference sites was calculated two ways, as fish per area surveyed and as fish per shoreline length. The number of fish per shoreline length (m) was calculated as fish/area (m^2) times the distance from the shore to 1 m depth. Overall, the density of Chinook salmon (fish/m^2) was not significantly different between delta areas and lake reference sites (Wilcoxon test, $Z = 1.6$, $P = 0.11$). In 9 of 14 tributaries (at least 10 Chinook salmon observed), the delta area had a higher mean density than the lake reference site (Figure 22 and 23). The abundance of Chinook salmon per shoreline length was, however, significantly different between delta areas and lake reference sites (Wilcoxon test, $Z = -2.4$, $P = 0.016$). Because many of the deltas had large shallow areas that extended out from shore further than the average lake nearshore area (area to 1 m depth), the number of Chinook salmon per shoreline length of deltas was often substantially higher than that of lake reference sites (Figure 22 and 23). At delta areas where the abundance was either lower or similar to the lake reference site, the delta was usually quite small (SW Sammamish Trib., East Mercer Trib., West Mercer Trib., and Denny Creek). At Coal Creek, the lake reference site was 1.2 km closer to the Cedar River than the Coal Creek delta area, which may have resulted in a lower delta:lake reference ratio.

We surveyed the convergence pools of 15 tributaries. The size of the convergence pool varied greatly depending on lake level. The density of juvenile Chinook salmon in the convergence pool was lower than that of the delta area and lake reference site in 10 of 13 (two other convergence pools had no delta for comparison) locations. In two of the other three tributaries, few fish were seen in any of the three habitats. Of the tributary habitats, juvenile Chinook salmon were most often observed in the convergence pools. However, in only four tributaries (Johns Creek, Taylor Creek, Lyon Creek and Tibbetts Creek) did we observe more than 10 juvenile Chinook salmon in the convergence pool (Figure 24). Use of convergence pools appeared to be most pronounced in small and medium-sized tributaries that were close to the Cedar River, Issaquah Creek, or the Sammamish River. These convergence pools were generally shallow. Large, deep convergence pools, found in large tributaries, appeared to be avoided. Within the large convergence pool at Tibbetts Creek, almost all Chinook salmon were observed at the shallow, downstream end (primarily sand substrate) and were rare in deep upstream areas (1.7 m maximum depth, primarily silt substrate).

Upstream of the convergence pools, juvenile Chinook salmon were observed in substantial numbers in only four tributaries. In March-May, they were observed in Johns Creek, Schneider Creek, and Lower Thornton Tributary (the secondary tributary of Thornton Creek). The density of Chinook salmon was highest in Johns Creek and Schneider Creek (Figure 24). After the hatchery fish were released, Chinook salmon were also observed in Lyon Creek in June. These four tributaries were small to medium-sized tributaries with a low gradient. Except for Lower Thornton Tributary, they were relatively close to a major spawning tributary (Cedar River or Issaquah Creek) or migration corridor (Sammamish River). The juvenile Chinook salmon that were observed in Lower Thornton Tributary may have originated in Thornton Creek. Juvenile Chinook salmon were observed primarily in glide and pools. In Lower Thornton Tributary, they were located along the edges of a small pond. In some of the other streams, the gradient was too steep and small fish would have difficulty moving upstream. Large tributaries, such as May Creek, Thornton Creek, and Tibbetts Creek, had a low gradient and a large amount of available habitat but very few Chinook salmon were observed. A deep convergence pool and other deep pools may have restricted the upstream movements of Chinook salmon through increased predation risk.



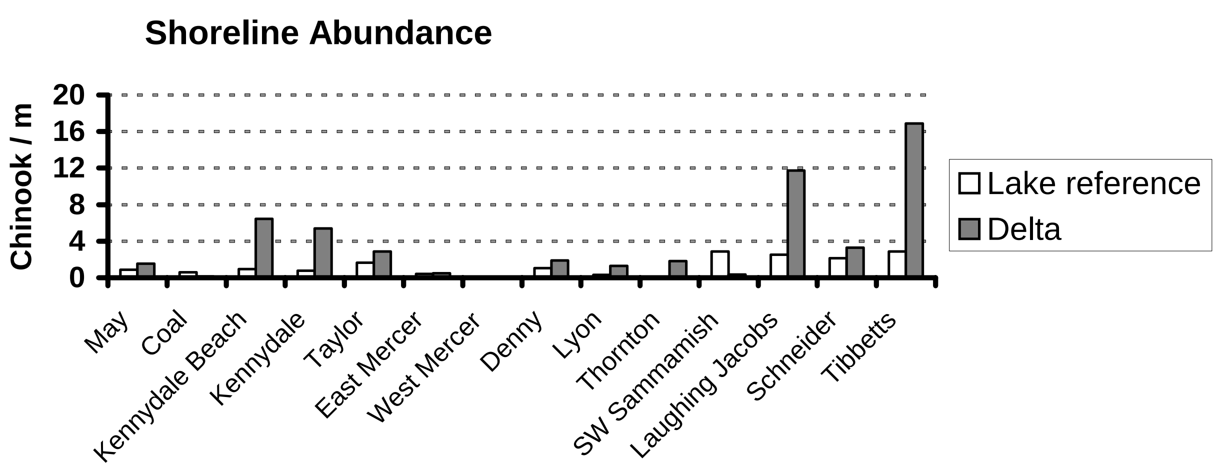
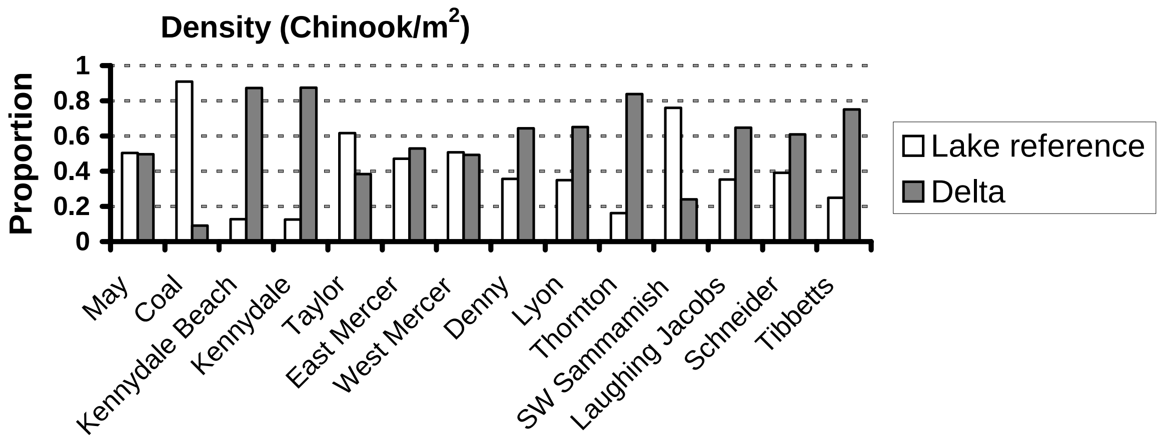


FIGURE 22. Mean density (Chinook salmon/m^2) and mean shoreline abundance (Chinook salmon/m of shoreline) of juvenile Chinook salmon at the delta site compared to a nearby lake reference site, March-June, 2002. Only sites with at least 10 Chinook salmon (combined) observed are shown. The first six tributaries are in south Lake Washington, the next three are in north Lake Washington and the last four are in south Lake Sammamish.



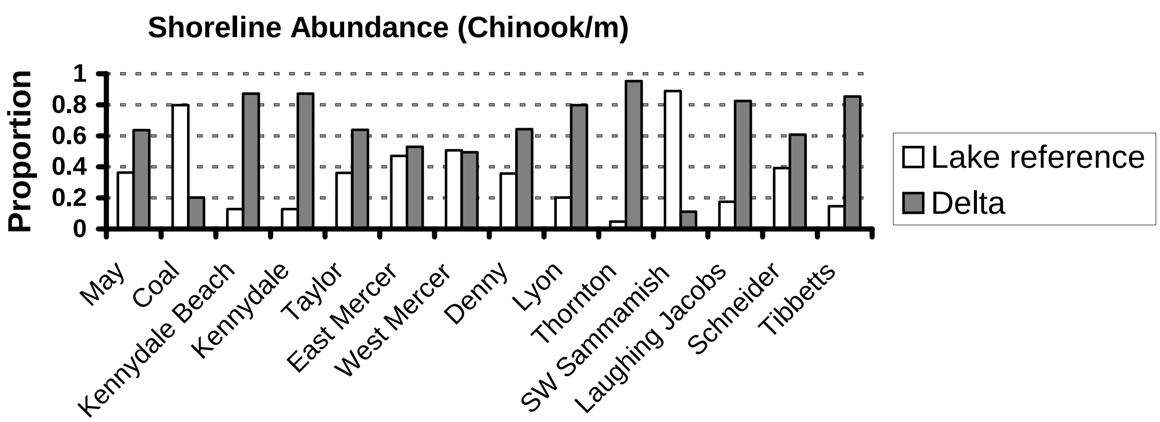


FIGURE 23. Ratio of juvenile Chinook salmon mean density (Chinook salmon/m^2) and mean shoreline abundance (Chinook salmon/m of shoreline) at the delta site compared to a nearby lake reference site, March-June, 2002. Only sites with at least 10 Chinook salmon (combined) observed are shown. The first six tributaries are in south Lake Washington, the next three are in north Lake Washington and the last four are in south Lake Sammamish.

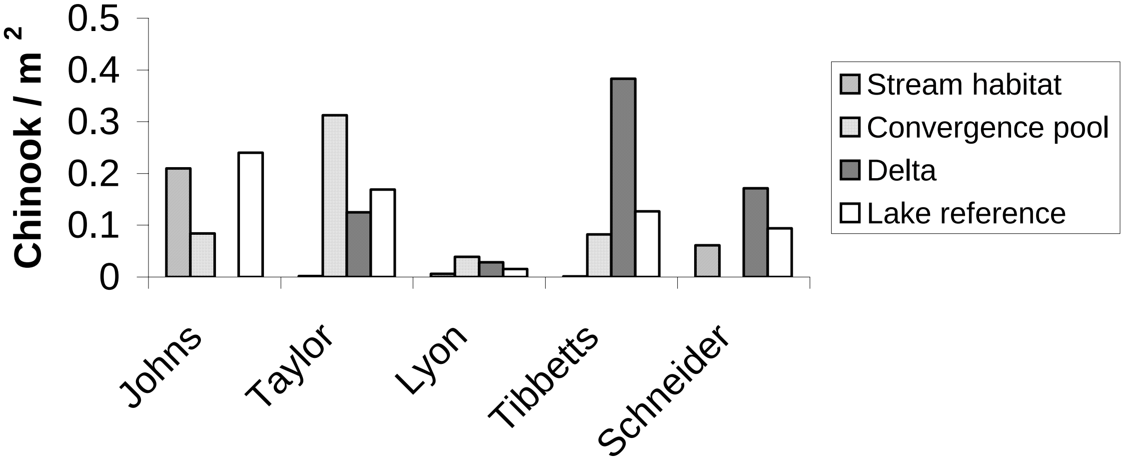


FIGURE 24. Mean density of Chinook salmon (number/m^2) in stream habitat and convergence pool of five tributaries compared to the mean density at the delta site and a nearby lake reference site, March-June, 2002. Only sites with at least 10 Chinook salmon (combined) observed in either the stream habitat or convergence pool are shown. The first two tributaries are in south Lake Washington, the next one is north Lake Washington and the last two are in south Lake Sammamish. No delta site was surveyed at Johns Creek.

South Lake Washington.– Johns Creek is a small, low gradient stream in the southeast corner of Lake Washington (Figure 4). It is 1.5 km from the mouth of the Cedar River and is the closest to the Cedar River of any tributary that we surveyed. The mouth of Johns Creek is at the south edge of the Gene Coulon Park boat launch. Because there was no well-defined delta area, no delta surveys were conducted. The stream had a long convergence pool (68 to 133 m in length depending on lake level). The lower 0.46 km of the stream can be easily surveyed except for four sections in culverts. Upstream the stream splits into two roughly equal-sized tributaries. Except for a few meters at their confluence, these tributaries appeared to be completely in culverts and appeared to lack any suitable rearing habitat. We routinely surveyed the lower 0.26 km of the stream. The upper section (rkm 0.26-0.46) was surveyed on two occasions.

Large numbers of juvenile Chinook salmon were observed in Johns Creek from February to May. More Chinook salmon were observed in Johns Creek during this time period than all the other tributaries combined. The peak number of juvenile Chinook salmon observed in the index area of Johns Creek was 387 on March 7 (Figure 25). The upper area was also surveyed on this date and an additional 116 Chinook salmon were observed. Assuming the stream area not surveyed (area in culverts) had a similar density of fish as the area surveyed, the total number of Chinook salmon in the lower 455 m would be 563. Juvenile Chinook salmon were found at the furthest upstream location surveyed.

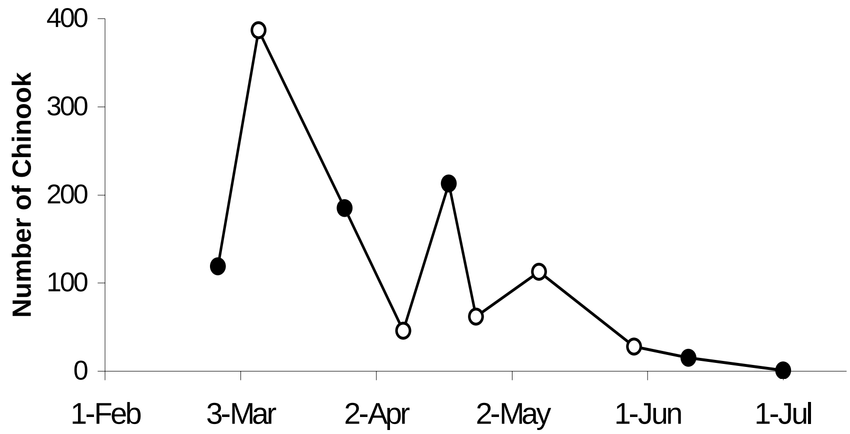


FIGURE 25. Number of juvenile Chinook salmon observed in the lower 259 m of Johns Creek, February-July, 2002. Open circles are daytime counts and closed circles are nighttime counts. Data are a combination of surface and snorkeling observations.

During February-April, juvenile Chinook salmon were observed in shallow, low velocity habitats including glides (Photo 7) and shallow areas of pools (tailouts and pool margins). Chinook salmon were also found in two small side channels. In May and June, almost all of them were present in pools and rarely found in glides. Within the pools, Chinook salmon were in the deepest part of the pool (Photo 8). On each survey date, the overall density (fish/m^2) of Chinook salmon was higher in the stream habitat (pools, glides, and riffles) than in the convergence pool (Wilcoxon test = 2.7, n = 9, P = 0.008).

Other salmonids in Johns Creek consisted primarily of sockeye salmon fry. Unlike other tributaries, few trout or juvenile coho salmon were present in Johns Creek. Other fish in Johns Creek included sculpins, juvenile brown bullhead, juvenile suckers, juvenile peamouth, and adult carp. These fish were observed primarily in the convergence pool in May and June.

PHOTO 7.-- Stream habitat at Johns Creek. Shown is a glide where juvenile Chinook salmon were common in March and April but rare in May and June.

PHOTO 8.-- Group of juvenile Chinook salmon in a small pool in Johns Creek. The photo was taken in early May when the Chinook salmon were primarily occupying the deepest area of each pool.

Kennydale Creek is a small, steep stream that enters the lake in the north part of Gene Coulon Park (Figure 4). The stream was almost entirely riffle habitat with little pool or glide habitat. The stream had a small delta area, which was composed almost entirely of sand. The density was 3 to 18 times higher on the delta than the lake reference site; however the differences were not significantly different (Wilcoxon test = 4.0, $n = 4$, $P = 0.068$), largely because of the small sample size. After the lake level rose in April, a small convergence was present and a few Chinook salmon were observed in this habitat. No Chinook salmon or other fish were observed upstream of the convergence pool.

At the north end of Kennydale Beach Park is a small, steep tributary. We only surveyed the delta area and a lake reference site (the swim beach at the park). The delta area consisted of sand and covered a relatively small area. The tributary was not surveyed because it was steep and inaccessible; the lower 10 m was covered by a dense stand of blackberry bushes and upstream the creek was in a culvert. The density of juvenile Chinook salmon was significantly higher (1.4 to 12 times higher) at the delta than at the lake reference site (Wilcoxon test, $n = 6$, $Z = 2.2$, $P = 0.028$).

The largest tributary surveyed was May Creek, which enters the lake along the southeast shore (Figure 4). We surveyed the lower 278 m of stream from the Lake Washington Boulevard bridge downstream to the mouth. This reach is all within the Barbee Lumber Mill property. The delta area sits between two rip rapped shores that extend diagonally out from the mouth. We used the Kennydale Beach Park swim beach as the lake reference site, which was 0.6 km south from the mouth of May Creek. In March, there was no convergence pool; however, as the lake level rose, a convergence pool was formed. Upstream, 80% of the stream length was riffles. Snorkel surveys included three pools and one glide. The density of juvenile Chinook salmon was similar between the lake reference site (mean, 0.058 m^2) and delta area (mean, 0.058 m^2)(Wilcoxon test, $n = 4$, $Z = -0.37$, $P = 0.72$). Only two Chinook salmon were ever observed in the tributary, one in the convergence pool and one in a pool. Juvenile coho salmon were present primarily in the convergence pool, while large trout primarily occupied the upstream pools. Small resident trout were scattered throughout the study reach.

Coal Creek is a relatively large tributary on the southeast shore of Lake Washington (Figure 4). The mouth of Coal Creek is located about 1 km southeast of the I-90 bridge. The stream system has a large delta and a long convergence pool (90-100 m long). Our study area included the delta, convergence pool, a long riffle, and a glide. There was no good lake reference site close to Coal Creek, so we used the Newcastle Beach index site, which was approximately 1.2 km south of Coal Creek. Coal Creek was sampled three times (once in April, May, and June). The density of juvenile Chinook salmon was higher at the reference site than the delta area on all three surveys. Only two Chinook salmon were ever observed at the delta area. No Chinook salmon were observed in the tributary. Juvenile coho salmon were present throughout the tributary, especially in the convergence pool (mean density, 0.17 fish/m^2) and glide (mean density, 0.10 fish/m^2). Trout were also present throughout the tributary. Several large trout (> 150 mm FL) were observed in the convergence pool. No coho salmon or trout were observed on the delta

The only tributary surveyed on the southwest shore of Lake Washington was Taylor Creek (Figure 4). Other creeks in this area are in culverts and enter the lake in deeper waters. Taylor Creek is a small stream that enters the lake approximately 2.8 km from the mouth of the Cedar River. The study reach was the lower 77 m of the creek that was located between residential homes. Pool habitat consisted of a few small plunge pools and a small convergence pool. The creek had a moderate-sized delta with sand and small gravel. Juvenile Chinook salmon were mostly observed in the delta, lake reference site, and the convergence pool. There were no significant differences in Chinook salmon density between the three sites (Freidman test = 1.2, n = 5, P = 0.55). Other than three Chinook salmon observed in the lowest plunge pool on May 16, no Chinook salmon were observed upstream of the convergence pool. Other salmonids that inhabited Taylor Creek included juvenile coho salmon and small trout < 150 mm FL.

The survey area in West Mercer Tributary consisted only of a 19-m-long convergence pool. Immediately upstream were two short waterfalls that were impassable for juvenile Chinook salmon. There was no distinct delta with fine sediments. Few Chinook salmon were seen at any of the habitats surveyed at West Mercer Tributary. Out of six surveys, no juvenile Chinook salmon were ever observed in the convergence pool, only one was observed in the delta area, and 10 were seen at the lake reference site. However, large numbers of juvenile coho salmon were present at West Mercer Tributary. The number of juvenile coho salmon observed on all habitats combined ranged from 52 on March 25 to 150 on June 4. Early in the sampling period, when juvenile coho salmon were small, the vast majority was located in the convergence pool. However, as the coho salmon grew, more and more of them were in the lake at the reference site, which was a few meters away from the tributary mouth. In March, none of the coho salmon observed were in the lake but afterwards the percentage increased to 4% in April, 16% in May, and 37% in June. No trout were observed in this creek or delta area.

The Lincoln Landing Tributary is a small, high gradient tributary (Table 6) on the north side of Mercer Island (Figure 4). The lower part of the creek was mostly riffle habitat with a few small, shallow pools. The deepest pool was only 0.3 m deep. There was no distinct delta area with fine sediments. No Chinook salmon were ever observed at any location during four surveys of the Lincoln Landing tributary. The only fish observed in the tributary were a few juvenile coho salmon and one trout.

The East Mercer Tributary enters the lake via a culvert and thus we were only able to survey the delta area and lake reference site. In March and April, when the lake level is low, the culvert was at the lake surface but in May and June the culvert was approximately 0.3-0.4 m below the lake surface. There was no distinct delta with fine sediments. The lake reference site had a higher density of Chinook salmon than the delta on six of seven survey dates; however the differences were not significant (Wilcoxon test, Z = -1.1, P = 0.24). Most of the juvenile Chinook salmon were located to the north of the tributary along a sandy beach within the lake reference site. The substrate at the delta area was primarily gravel and cobble. Juvenile coho salmon and trout were common at the delta and lake reference site. In contrast to Chinook salmon abundance, the density of trout was higher at the delta area (mean, 0.050 fish/m^2) than at the lake reference site (mean, 0.018 fish/m^2) (Wilcoxon test, Z = -2.0, P = 0.043). Additionally, the density of juvenile coho salmon was higher at the delta on five of seven survey dates than at the lake reference site (Wilcoxon test, Z = -2.0, P = 0.046).

<u>North Lake Washington</u>.– Lyon Creek is the closest stream to the outlet of the Sammamish River that we surveyed (Figure 5). The study reach of Lyons Creek had a low gradient and a long, shallow convergence pool. Lyon Creek was surveyed three times, once in April, May, and June. Eighty-three percent of all the Chinook salmon (n = 53) seen were observed during the June survey. Presumably, many of these fish were hatchery fish which were released from the Issaquah Hatchery in late May. Chinook salmon were present in most survey locations including four Chinook salmon that were present in the furthest upstream location we surveyed, a glide 136 m from the lake. Other salmonids were abundant in Lyon Creek. In May and June, juvenile coho salmon were abundant in the convergence pool. For example, 179 coho salmon (0.78 fish/m^2) were observed in the June survey. Lyon Creek had the highest densities of trout observed of any stream surveyed. Combined, we counted 257 trout in Lyons Creek for the three surveys. Almost all of the trout were < 150 mm FL and many appeared to be age-0 trout.

A short distance to the west of Lyon Creek is McAleer Creek (Figure 5). We surveyed the lower 80 m of McAleer Creek, most of which was a deep convergence pool (maximum depth, 1.7 m). We were only able to complete one survey (April 2) at McAleer Creek because of frequent turbidity problems. Only two Chinook salmon were observed during this survey, one at the lake reference site and another one in the convergence pool. Similarly to other tributaries, juvenile coho salmon were mostly found in the convergence pool and trout were present primarily in glide and pool habitat upstream of the convergence pool.

Thornton Creek is a large tributary that is the furthest away from the Sammamish River of the tributaries we surveyed in the north Lake Washington area (Figure 5). The delta at Thornton Creek was one of the largest of the tributaries we surveyed. The stream had a large, deep convergence pool (190 m long by 4.6 m wide) that was armored on both banks with rip rap. We surveyed the lower 30 m of the convergence pool. We surveyed pools and glides from the NE 93rd Street bridge to the Sand Point Way bridge. Few juvenile Chinook salmon were observed on the delta and the lake reference site. The density of Chinook salmon was higher at the delta on all three survey dates. Because of the small sample size, it is difficult to detect significant differences between the two sites. Within Thornton Creek proper, only three Chinook salmon were observed, one in the convergence pool and two in an upstream pool. Juvenile coho salmon were scattered throughout the study area. Trout were present primarily in the upstream pools, which included several > 150 mm FL.

Within the lower part of Thornton Creek, we also surveyed a small secondary tributary (Lower Thornton Trib.) that enters Thornton Creek 30 m upstream of the mouth (Figure 5). The lower part of this secondary tributary consisted of a convergence pool. Upstream of this pool was a short cascade and then a small pond that was 22 m long, 17 m wide and had a maximum depth of 1.5 m (Photo 9). Upstream of the pond, the stream flowed though a small wetland, which we did not survey. Most of the juvenile Chinook salmon observed in Thornton Creek system, were in the pond of this small, secondary tributary. A total of 12 Chinook salmon were observed in the pond (two survey dates); whereas, only three Chinook salmon were ever observed in Thornton Creek. In April, coho salmon were only observed in the convergence pool. However, in May most of the coho salmon were in the pond. The short cascade appeared to be a barrier to juvenile coho salmon until the lake level rose and the cascade became passable.

Denny Creek is a small creek located along the northeast shore of Lake Washington (Figure 5). The lower reach of the stream is located within Denny Park. The lower reach was mostly riffles with a few small, shallow pools (combined made up 28% of the length of the study reach). There was no well-defined delta at Denny Creek. No Chinook salmon were observed at any of the survey locations until June, when several Chinook salmon were seen at the lake reference and delta sites. The delta (0.57 fish/m^2) had a higher density than the lake reference site (0.32 fish/m^2). No Chinook salmon were observed in the convergence pool or other areas of the creek. Juvenile coho salmon were the most abundant salmonid present in the convergence pool. Upstream, small trout < 150 mm FL were the dominant salmonid. The few trout that were collected and identified were all cutthroat trout.

South Lake Sammamish.– Laughing Jacobs Creek is a medium-sized tributary located in the southeast corner of Lake Sammamish (Figure 6). The study reach was composed primarily of riffle habitat. Pools and glides made up only 17% of the study reach. The substrate was primarily cobble and sand. Most of the large substrates were heavily embedded in sand. The stream had a medium-sized delta, which was composed almost entirely of sand. In our early sample (April 30, prior to the release of hatchery fish), we observed a total of 15 Chinook salmon on the two delta transects. However, after the hatchery fish were released, a total of 105 Chinook salmon were observed on the same transects. The density of Chinook salmon was one of the highest of any location surveyed. Within the tributary, we only surveyed the convergence pool on April 30 but surveyed the entire study reach on June 5. Chinook salmon were not observed in the tributary on either survey date. Due to the lack of suitable habitat, we assume that juvenile Chinook salmon rarely use the lower section of Laughing Jacobs Creek.

Tibbetts Creek is a relatively large tributary (Table 6; Photo 10) with a large delta. The study reach had a low gradient (< 1 %). The convergence pool (218 m long by 6.4 m wide) was the largest and deepest (maximum depth, 1.7 m) of any tributary surveyed. Because of the large size of the convergence pool, we only surveyed the lower 79 m. Upstream of the convergence pool was primarily pool habitat. The pool maximum depth ranged from 0.5 to 1.7 m (mean, 0.9 m). Because of high turbidity, we were unable to survey the delta and convergence pool in late April. Juvenile Chinook salmon were abundant on the delta in June and their overall density was higher than the lake reference site. In June, 13 Chinook salmon were observed in the convergence pool but all but one were located near the mouth in the 30-m downstream end, which was shallow with a primarily sand substrate. The upstream part of the convergence pool, where only one Chinook salmon was observed, was deep (1.7 m maximum depth) with silt substrate. Upstream of the convergence pool, we only observed one juvenile Chinook salmon in an 87-m section that was surveyed in April and June.

PHOTO 9.-- The small pond of the Lower Thornton tributary. The tributary enters Thornton Creek 30 m upstream of the mouth on Lake Washington. Most of the juvenile Chinook salmon observed in the Thornton Creek system, were observed in this small pond. Lake Washington is located in the background.

PHOTO 10.-- Stream habitat of Tibbetts Creek, a tributary to Lake Sammamish. Tibbetts Creek was one of the large tributaries surveyed. Few juvenile Chinook salmon were observed in the stream habitat of Tibbetts Creek.

Schneider Creek is a small, low gradient stream that is a short distance to the west of Tibbetts Creek (Figure 6). The study reach sits in a straight, narrow channel that appears to have been dug out to drain a wetland. Within the study reach, 82% of the habitat was composed of glides or pools, all which were relatively shallow. Only one pool was deeper than 0.4 m, besides the convergence pool, which had a maximum depth of 0.8 m. During the first survey on April 30, 11 juvenile Chinook salmon were observed in the stream. All were upstream of the convergence pool. Chinook salmon were present at the furthest upstream location (culvert under I-90) surveyed, 194 m from Lake Sammamish. No Chinook salmon were observed in the June survey; however, they may have been missed due to some turbidity problems caused by startled juvenile coho salmon and trout. Juvenile Chinook salmon were present on the tributary delta on both survey dates and their abundance appeared to be similar to the lake reference site. Large numbers of juvenile coho salmon were present throughout the Schneider Creek study reach.

The SW Sammamish Tributary is a small, high gradient tributary. The creek was mostly riffle habitat with a few small, shallow pools and a small convergence pool depending on the lake level. There was no distinct delta area with fine sediments. Of the two survey dates (April 18 and June 5), no Chinook salmon were observed in the creek habitat and only two were observed on the delta, both on June 5. Fish observed in the tributary were primarily juvenile coho salmon and small trout.

<u>Diet analysis</u>.– At the Kennydale Creek and a lake reference site, a total of 16 juvenile Chinook salmon were sampled on April 11 for diet analysis. The mean length of Chinook salmon collected at the two sites was similar (Table 7; t-test = -0.30, P = 0.77). All fish sampled had some prey in their stomachs. The mean weight of stomach contents appeared to be similar between the two sites (Table 7). The overall diet was noticeably different between the two sites. Juvenile Chinook salmon collected along the lakeshore had consumed primarily chironomid pupae, representing 92% of the diet by weight and 75% numerically. In contrast, chironomid pupae accounted for only 13% of the diet by weight of fish collected at the mouth of the tributary. Instead, they consumed a wide variety of prey types composed largely of other aquatic insects (52% of the diet by weight). Because there was a large difference in the diet and stream dwelling macroinvertebrates (i.e., plecoptera and ephemeroptera) were found in their stomachs, Chinook salmon may be feeding to some extent on prey items that drifted downstream from Kennydale Creek.

TABLE 7. Prey consumed by juvenile Chinook salmon at two nearshore sites in Gene Coulon Park, Lake Washington, April 11, 2002. Fish were collected at the mouth of the Kennydale Creek and at a lake reference site, 150 m south of the tributary. The number of fish sampled (N) and the mean fork length (FL) is also indicated.

	Reference site N = 10 mean FL = 45.8 mm				**Tributary mouth** N = 6 mean FL = 46.2 mm			
	Number		Weight		Number		Weight	
Prey group	#	%	g	%	#	%	g	%
Insects								
Diptera								
Chironomid pupae	105	75.0	0.137	92.4	12	15.0	0.008	13.1
Chironomid larvae	13	9.3	0.001	0.7	21	26.3	0.008	13.1
Other Diptera larvae	0	0	0	0	16	20.0	0.009	14.8
Ephemeroptera	0	0	0	0	5	6.3	0.009	14.8
Plecoptera	0	0	0	0	1	1.3	0.004	6.6
Collemba	1	0.7	0.0003	0.2	6	7.5	0.002	3.3
Misc. terrestrial insects	10	7.1	0.005	3.4	7	8.8	0.004	6.6
Crustacea								
Cladocera	11	7.9	0.005	3.4	0	0	0	0
Amhipoda	0	0	0	0	1	1.3	0.002	3.3
Oligochaete	0	0	0	0	2	2.5	0.004	6.6
Nematode	0	0	0	0	7	8.8	0.004	6.6
Other	0	0	0	0	2	2.5	0.007	11.4
Total	140	--	0.148	--	80	--	0.081	--
Mean	14.0	--	0.015	--	13.3	--	0.014	--

DISCUSSION

INDEX SITES

A potential problem with the index surveys was differences in the habitat quality between sites. We selected sites that had high quality habitat for juvenile Chinook salmon. Habitat characteristics included small substrates (primarily sand), gentle slope, and no shoreline armoring. For the most part, we were able to find sites that were mostly sand and had a gentle slope (Table 1), but we had difficulty finding enough sites with no shoreline armoring. Over 70% of the shoreline of Lake Washington is armored (Toft 2001) and in the south end there are long stretches of shoreline with residential homes and the shoreline is almost all armored. We used a few sites with armoring but the wetted depth of the armoring was minimal in March and early April. Of the Chinook salmon that were associated with armored banks in 2001, most were found where the wetted depth of the armoring was relatively shallow (Tabor and Piaskowski 2002). As the lake level rises, the wetted depth of the armoring greatly increases in late April and May. At some armored index sites such as Kennydale Beach, the density of Chinook salmon may have been reduced somewhat due to the armoring. How much the densities were reduced is unclear. Because the wetted depth of the armoring was relatively shallow (0 – 0.2 m) from January to early April and armoring did not occur along the entire transect length, we do not believe the armoring significantly altered the overall results.

From February to May, juvenile Chinook salmon were concentrated in the south end of Lake Washington. The nearshore areas in the south end appear to be important nursery areas for juvenile Chinook salmon originating from the Cedar River. Based on 2002 index and restoration surveys as well as 2001 surveys, the northern boundary of the nursery area is approximately Pritchard Beach on the west shoreline and the mouth of May Creek on the east shore (see Figure 1). North of these sites, the number of Chinook salmon would be expected to be relatively low until mid-May or June. Because Chinook salmon are closely associated with nearshore habitats from February to May, restoring and protecting shallow water areas in the south end would be particularly valuable. Shoreline improvements in more northern locations would be beneficial but the overall effect to the Chinook population would be small in comparison to restoration efforts in the south end.

Comparison of 2001 survey data to 2002 data suggested that the distribution of juvenile Chinook salmon may have been affected by cooler water temperatures in 2002 than 2001. Chinook salmon may have grown slower and thus remained in the nearshore areas for a longer time. Cooler temperatures may also have indirectly affected the distribution of Chinook salmon if the abundance of prey and predators was altered. At Gene Coulon Park index sites, Chinook salmon were abundant in the nearshore area later in the year in 2002 than 2001. Their abundance decreased rapidly from May 15 to June 7 in 2001; whereas, in 2002 Chinook salmon were still abundant on June 2 and their abundance decreased rapidly from June 2 to June 30. Additionally, cooler temperatures may have caused Chinook salmon to remain close to the Cedar River and limited their movements to more northern locations. Besides Gene Coulon Park, the only location that was sampled routinely in 2001 and 2002 was Seward Park. Fewer Chinook salmon were observed at Seward Park from February to May in 2002 than in 2001. Continuing index surveys in 2003 may be useful to determine if temperature is important in Chinook salmon distribution.

The use of Mercer Island by Chinook salmon from February to May was thought to be rare because Chinook salmon are closely associated with nearshore areas during this time period and would have to swim across open water where they may be extremely vulnerable to predators. Data from this study as well as recent beach seining efforts in 2000 and 2001 by WDFW (K. Fresh, unpublished data) indicates that small Chinook salmon commonly occur on Mercer Island, albeit in small numbers. However, there are no data that suggest that the low abundance is an island effect. Their abundance appears to be simply a function of the distance from the mouth of the Cedar River. In Hood Canal, chum salmon fry (*O. keta*), which also inhabit nearshore areas, have been documented to quickly swim across the canal to the other shoreline within a few days after being released from the hatchery (Bax et al. 1978).

RESTORATION SITES

The abundance of juvenile Chinook salmon at Seward Park sites was surprisingly low. We had expected good numbers of juvenile Chinook salmon to occur in 2002 because several juvenile Chinook salmon were observed at Seward Park in 2001 and the number of spawning adults in the Cedar River was substantially higher in 2001 than 2000. Why such low numbers of Chinook salmon were observed in Seward Park is unclear. Surveys of index sites indicated Chinook salmon were abundant in south Lake Washington but were concentrated in the south end. One possibility is that cooler lake temperatures in 2002 may have decreased the movement of juvenile Chinook salmon to northern locations such as Seward Park. Another possibility is that the number of juvenile Chinook salmon that move north past Pritchard Beach varies widely from year to year but the total number is always extremely low compared to the south end.

Within Seward Park sites, we did not observe an increase in the proportion of Chinook salmon that used the restored site compared to other sites. This may have been partly due to the small sample size and thus, a change in Seward Park Chinook salmon distribution may be apparent if large numbers had been present. Also, the low use of the restored site may have been related to low prey availability. The major prey of juvenile Chinook salmon is chironomids (Koehler 2002) whose abundance may have been quite low because the substrate was new. Chironomids may not have fully colonized the restored site and the new substrate may not be suitable for chironomid production. Because of questions regarding Chinook salmon movements in cooler water and possible low prey availability, it may be beneficial to survey the restored sites and other Seward Park sites again in 2003.

In 2001, we made some preliminary observations on the use of soft substrates (silt and mud) by juvenile Chinook salmon, which suggested that they tend to avoid this substrate type. Results from surveys at Beer Sheva Park provided further evidence that Chinook salmon do not extensively use soft substrates. The reasons why soft substrates are avoided is unclear. Soft substrates appear to have more macrophytes than other substrate types and Chinook salmon may prefer a more open environment. Another possibility may be that these substrates may be associated with a higher density of predators such as largemouth bass and brown bullhead.

WOODY DEBRIS AND OVERHANGING VEGETATION

We had originally hypothesized that during the day juvenile Chinook salmon would extensively use the experimental woody debris piles in March and April when Chinook salmon were small and close to shore. We did not observe that general trend; although, we did observe substantially more Chinook salmon in woody debris than in the control sites on a couple of dates in April. The pattern of woody debris use is somewhat unclear. At times, Chinook salmon make extensive use of woody debris and other times its rarely used. The use of woody debris is probably related to several factors such as light intensity, turbidity, time of day, prey availability, and the presence of potential predators. In general, juvenile Chinook salmon appear to be quite flexible in their behavior and habitat use. Typically, the behavior of Chinook salmon could be classified as one of two types; active in open water or inactive in some type of cover. At the experimental woody debris site, most Chinook salmon were active, in 0.4-1.0 m deep water, occasionally were observed feeding at the surface, and if they were near woody debris they were located near the periphery of the debris pile. Although not as common at the woody debris piles, we often observed Chinook salmon that were inactive, in 0.3-0.5 m deep water, and located directly under woody debris. This type of behavior was also commonly observed at the natural OHV/SWD sites.

Monitoring of the vacant lot and Gene Coulon island site indicated that overhanging vegetation in combination with woody debris or possibly by itself is a preferred habitat type for juvenile Chinook salmon. The use of woody debris alone was experimentally tested in 2001 and 2002 and no preference for this habitat type was detected. Therefore, overhanging vegetation appears to be an important element of the nearshore structure. In the Cedar River, the presence of overhanging vegetation appears to be an important factor affecting the occurrence of juvenile Chinook salmon (R. Peters, unpublished data). In Lake Washington, an additional experiment to test the use of overhanging vegetation alone and in combination with woody debris would be beneficial to understand how juvenile Chinook salmon respond to nearshore structures.

TRIBUTARIES

Delta areas appeared to be especially valuable habitat for juvenile Chinook salmon. Of the various tributary habitats examined, the delta areas appeared to be the most utilized. In comparison to lake reference sites, the delta sites often had a higher density of juvenile Chinook salmon. Fresh et al. (2000) found that sites near tributary deltas had higher beach seine catch rates of Chinook salmon than did other lake beach seining sites. The deltas probably provide good habitat because they are shallow, have a gentle slope, and are composed primarily of sand. The habitat condition at deltas often resembles that of swimming beaches, where large numbers of juvenile Chinook salmon have often been observed (Tabor and Piaskowski 2002). Deltas typically have more shallow water habitat per shoreline length than most other locations in the lake because they often extend out into the lake a relatively long distance. Because deltas are often large and used extensively, they would be expected to have a higher overall abundance (number/shoreline length) than typical lake shorelines.

Deltas near the mouth of a creek appear to not only provide good shallow water habitat but may also be good foraging sites. Our small diet analysis showed juvenile Chinook salmon from the mouth of Kennydale Creek consumed different prey items than Chinook salmon from the lake shoreline. Based on the type of prey consumed, Chinook salmon appear to be consuming some prey that originated in the tributary and subsequently drifted downstream to the lake. In contrast to our results, Koehler (personal communication) found no apparent difference in the diet between Chinook salmon collected at tributary mouths and those collected at other Lake Washington sites. Several differences between the studies may explain the discrepancy between the data sets. We only sampled one small tributary on one date; whereas, Koehler's samples came from several sampling dates at several tributaries. We collected Chinook salmon precisely at the creek mouth with hand dip nets; whereas, Koehler collected fish with beach seines and thus, sampled a much larger area. Most of Koehler's samples came from tributaries in the north end of the lake and may have been collected mostly in June when other prey, such as *Daphnia* sp., are more abundant. Further sampling of tributary deltas needs to be undertaken to determine if tributaries are important forage locations. Additionally, tributary deltas may become particularly valuable foraging locations following a rain event because the drift of aquatic and terrestrial invertebrates may be substantially higher. K. Fresh (NOAA Fisheries, personal communication) observed that the abundance of juvenile Chinook salmon and other salmonids increased during a high streamflow event at some deltas. Therefore, further research should include sampling during high streamflow events as well as during normal streamflow conditions to compare the diet and abundance of juvenile Chinook salmon.

The majority of juvenile Chinook salmon we observed at our tributary sites were assumed to have originated from either the Cedar River, Bear Creek, or Issaquah Creek (hatchery or naturally-produced fish). However, in some cases, many of the fish we observed may have been spawned within the tributaries or possibly from some type of outplanting (such as a school science program which releases hatchery fish at locations close to their school). Of the tributaries examined, adult Chinook salmon have been documented to spawn in May Creek, Coal Creek, Thornton Creek, McAleer Creek and Laughing Jacobs Creek. We do not know if spawning occurred in any of these tributaries in 2001. However, in each of these tributaries, few if any juvenile Chinook salmon were observed. Juvenile Chinook salmon observed in the delta areas may have originated upstream in the tributary. This may have biased some comparisons between the deltas and lake reference sites. In past years, local schools have outplanted small numbers of juvenile Chinook salmon and fish could have been stocked into any of the tributaries examined. It is not known if this occurred in 2002.

Overall, few tributaries had large numbers of juvenile Chinook salmon. Often Chinook salmon used the delta but were rare in the tributary. Juvenile Chinook salmon appeared to use tributaries that had low gradient, were relatively small and shallow, and were close to their natal stream (Cedar River or Issaquah Creek). In some tributaries (i.e., Taylor Creek and Kennydale Creek), Chinook salmon only used the convergence pool because upstream the gradient was too high. In the lower part of the Fraser River, British Columbia, Chinook salmon used nonnatal tributaries that had low gradients and had no fish barriers such as waterfalls, culverts, bridge footings, or flood control gates (Murray and Rosenau 1989). The use of the lower reaches of tributaries by Chinook salmon has also been documented in the upper Fraser River system in

British Columbia (Scrivener et al. 1994) and the Taku River in Alaska (Murphy et al. 1989). In small, nonnatal tributaries of the Fraser River, juvenile Chinook salmon were found as much as 6.5 km upstream from the river (Murray and Rosenau 1989). The furthest upstream from Lake Washington we observed juvenile Chinook salmon was 0.46 km in Johns Creek. In most tributaries, we only surveyed a short stream section near the mouth of the creek. It is certainly possible that Chinook salmon may have moved upstream past our study reach.

The habitat of many of the tributaries we surveyed was relatively simple which may have limited the use of the tributaries by juvenile Chinook salmon. The streams were usually confined to a straight, narrow channel with little complexity. Little woody debris and few off-channel habitats were present. Additionally, riparian vegetation was often sparse. In the Cedar River, small woody debris, off-channel habitats, and riparian vegetation appear to be important elements of juvenile Chinook habitat use (R. Peters, USFWS, unpublished data). Johns Creek, which contained large numbers of Chinook salmon, was moderately complex. Some small woody debris and off-channel habitats were present. Additionally, moderate levels of riparian vegetation were also present. The creek also had four culverts, which may provide some overhead cover. Tributaries that have little complexity may provide little refuge for small fish during high flow events, especially since urban streams are usually quite flashy after rain events. Additionally, the lack of complex habitats may limit the amount of cover from predators.

The low abundance of juvenile Chinook salmon in the lower section (i.e., convergence pool) of many tributaries may also have been because the water was deep and the banks were armored with riprap. Previous sampling in Lake Washington demonstrated that shallow water habitat is an important element of Chinook salmon habitat use; especially from February to May when Chinook salmon are relatively small (Tabor and Piaskowski 2002). In many tributaries, the banks were steep due to rip rap and thus the amount of shallow water habitat was minimal. At Johns Creek, where Chinook salmon were abundant, the convergence pool was relatively wide and shallow, although some rip rap was present. At Tibbetts Creek, we observed several Chinook salmon near the mouth of the creek in the shallow part of the convergence pool and few were observed upstream in deeper areas of the pool. Deep water is probably avoided because of increased predation risk. Large trout and large sculpin were commonly observed in deep pools. Riprap may also provide suitable habitat for predators of Chinook salmon such as trout and large sculpin. In the Cedar River, the number of large sculpin ($\geq$ 50 mm TL) has been shown to be related to substrate size (Tabor et al. 1998).

An important consideration of urban tributaries as Chinook salmon habitat is water quality. If the habitat is improved but the water quality is poor, the tributary could be avoided by juvenile Chinook salmon or may be harmful to the health of the fish if they inhabit the tributary or its mouth. Of the tributaries we examined, Johns Creek was by far the most used by Chinook salmon. Although the habitat appeared to be good for salmonids, the water quality often appeared questionable. We observed a large, oily scum on some days, which often occurred following a rain event. Often the water had somewhat of a milky, white color. On May 29, we observed a short, temporary change in the water clarity; for several minutes the creek became milky white and changed from a turbidity of 0.85 to 14.6 NTU with no noticeable change in streamflow. In the past, fish kills have been documented at Johns Creek. Shepard and Dykeman

(1977) stated “a fish kill of over 100 juvenile trout in February 1976 was investigated by the Washington State Fisheries Department, and the creek was noted to be strongly green at the time.” The authors also indicated large fish kills occurred in 1974 and 1975. Preliminary water analysis indicated levels of cadium, zinc, and possibly nickel were near safe limits for salmonids (Shepard and Dykeman 1977). They also reported that water temperatures in the creek were substantially higher than the lake. However, we did not observe any apparent difference during similar times of the year. Water quality in Johns Creek may have improved since the 70's. Given the large numbers of juvenile Chinook salmon and the questionable water quality, further investigation of Johns Creek water quality is recommended. Water quality monitoring of other tributaries may be useful. Also, before any restoration project is undertaken, such as Mapes Creek, some information or monitoring of the water quality is needed.

In some tributaries (e.g., Schneider Creek, Coal Creek and West Mercer Trib.), large numbers of 0+ juvenile coho salmon were observed. The presence of these fish could have inhibited the use of these tributaries by Chinook salmon. In Johns Creek, where Chinook salmon were abundant, very few coho salmon were present. In controlled experiments, 0+ juvenile coho salmon have been shown to be dominant over 0+ juvenile Chinook salmon of the same size (Stein et al. 1972; Taylor 1991). Coho salmon may not dominate Chinook salmon in the tributaries we studied because coho salmon appeared to be substantially smaller than the Chinook salmon throughout the study period. Nevertheless, if a tributary has large numbers of juvenile coho salmon already present it could possibly inhibit the colonization by Chinook salmon.

Besides 0+ juvenile coho salmon, other salmonids were often abundant in the tributaries we examined. In particular, many of the streams, especially larger tributaries such as May Creek, Coal Creek, Lyons Creek, and Thornton Creek, had large numbers of trout. We were unable to identify many trout to species, but most of the trout we could identify were cutthroat trout. Also, all the small trout we captured with dip nets were cutthroat trout. Smaller trout may be competitors of food and space with juvenile salmon. We did not observe large numbers of 0+ trout until late May. Large trout (> 150 mm) may be predators of juvenile Chinook salmon and thus, could directly influence the abundance of juvenile Chinook salmon through predation and indirectly influence their distribution through intimidation. The presence of these large trout may inhibit Chinook salmon from moving upstream in many streams. Predation of Chinook salmon by large trout has been documented in Lake Washington (Tabor and Chan 1996) and the Cedar River (R. Tabor, unpublished data).

In general, juvenile Chinook salmon appeared to use small and medium-sized tributaries more extensively than large tributaries. Making comparisons between large and small tributaries is difficult because of the small number of tributaries surveyed and because of differences in the distance to the natal tributary. However, by comparing a large tributary to a nearby small tributary, it appears that small and medium-sized tributaries are preferred. For example, the density of Chinook salmon was over 10 times higher at the Kennydale Beach delta than at the May Creek delta. In the Lake Sammamish system, Schneider Creek is further away from Issaquah Creek than Tibbetts Creek, yet the density was over 20 times higher in Schneider Creek. Also, in the Thornton Creek system, 87% of the juvenile Chinook salmon were found in a small tributary near the mouth. At large tributaries, juvenile Chinook salmon were common on the deltas but were rare in the convergence pool and other stream habitats. The presence of large trout and large sculpin in the large tributaries may inhibit the use of the convergence pool and other stream habitats. In small and medium-sized tributaries, large trout and large sculpin were rare. Additionally, the convergence pool of large tributaries was usually deep and armored with riprap, whereas small tributaries tended to be shallower and have less armoring.

In the small and medium-sized, low-gradient tributaries, the stream habitat (pools, glides, and riffles) usually had higher densities of Chinook salmon than the convergence pool. In Schneider Creek, all Chinook salmon were observed upstream of the convergence pool. Densities of Chinook salmon in the stream habitat of Johns Creek were always higher than in the convergence pool on each survey date. In Lyon Creek, densities were higher in the convergence but few were present until June when they prefer deeper habitats. Also, the stream habitat area that we surveyed in Lyon Creek was mostly riffles and little pool or glide habitat was available. If a stream has high quality pools and glides, Chinook salmon may use the stream habitat more extensively than the convergence pool. Juvenile Chinook salmon may be more attracted to the stream habitat because of the higher water velocities, which may be better foraging locations.

In conclusion, our results indicate that nonnatal tributaries can be important habitat for juvenile Chinook salmon. The lower sections of many small tributaries are in culverts and enter the lake several meters below the lake surface and thus, are of little value to Chinook salmon. Restoring these streams to their natural location would provide additional habitat. Restoration efforts should concentrate on small, low gradient tributaries that are close to the outlets of the Cedar River, Sammamish River, or Issaquah Creek. Even high gradient tributaries could provide valuable habitat if a sizeable delta is developed. Tributaries further away from the major outlets will probably not be used extensively but some Chinook salmon may use these sites in May, June, and July.

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